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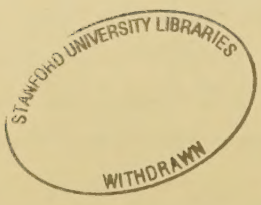
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UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

THE MESOZOIC AND CENOZOIC ECHINODERMATA OF THE UNITED STATES

BY

WILLIAM BULLOCK CLARK
AND
MAYVILLE W. TWITCHELL

DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY WITH THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

BY

MAYVILLE W. TWITCHELL.

JUNE, 1905.

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1915

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PREFACE.

The study of the Mesozoic and Cenozoic Echinodermata of the United States was commenced by the senior author of this paper under the auspices of the United States Geological Survey in the autumn of 1890 and has been continued with frequent interruptions to the present time. During recent years he has had associated with him, in the study of the Cenozoic forms, Dr. M. W. Twitchell, formerly a graduate student at Johns Hopkins University and now assistant State geologist of New Jersey, who has confined his investigations chiefly to the Clypeastrina and Asternata. Several papers containing results of this study have been prepared by the senior author, the most important being one entitled "The Mesozoic Echinodermata of the United States," which was published in 1893 as Bulletin 97 of the United States Geological Survey. Other contributions have appeared from time to time as the work has proceeded.

Few American paleontologists have investigated the Echinodermata, and no one of them has hitherto attempted a general systematic study of the Mesozoic and Cenozoic representatives of this group. Much confusion has therefore existed as to the specific and generic relations of many of the forms, and their geologic distribution has been in much doubt. Some of the forms are very numerous, and because of their wide geographic and restricted geologic range are valuable in determining questions of correlation. The revision presented in this contribution should therefore be of some value in stratigraphic geology.

No attempt has been made by the authors to modify materially the recent classifications of the Echinodermata, which are based on exhaustive study of far greater and much more representative materials than those afforded by American deposits. The authors have followed very closely in their major classification that of F. A. Bather in "The Echinodermata," in Lancaster's "Treatise on zoology," and in their generic usage that of P. M. Duncan in his "Revision of the genera and great groups of the Echinoidea."

Many courtesies have been extended to the writers in connection with this study, and all the large collections of the country have been put at their disposal. Among the more extensive collections used have been those of the United States Geological Survey, United States National Museum, Academy of Natural Sciences of Philadelphia, American Museum of Natural History, Wagner Free Institute of Science, Museum of Comparative Zoology of Harvard College, Peabody Museum of Yale University, Cincinnati Society of Natural History, Walker Museum, Carnegie Museum, Field Museum, Boston Society of Natural History, Johns Hopkins University, Williams College, University of California, Leland Stanford Junior University, Amherst College, Maryland Geological Survey, New Jersey Geological Survey, Texas Geological Survey, Alabama Geological Survey, P. de Loriol, and Robert T. Jackson.

The authors desire particularly to express their appreciation for valuable personal aid rendered by numerous paleontologists, among whom should be especially mentioned T. W. Stanton, of the United States Geological Survey; J. W. Gregory, of the University of Glasgow; W. H. Dall, of the United States National Museum; Robert T. Hill, formerly of the United States Geological Survey; Frank Springer, of the United States National Museum; John C. Merriam, of the University of California; and Ralph Arnold, until lately of the United States Geological Survey.

Most of the illustrations have been made under the direction of J. L. Ridgway, of the United States Geological Survey. Many of the earlier drawings from Bulletin 97 (The Mesozoic Echinodermata of the United States), made by C. R. Keyes and H. C. Hunter, are incorporated in this volume.

THE MESOZOIC AND CENOZOIC ECHINODERMATA OF THE UNITED STATES.

By William Bullock Clark and Mayville W. Twitchell.

PART I.—THE MESOZOIC ECHINODERMATA.

By William Bullock Clark.

INTRODUCTION.

GEOLOGIC AND GEOGRAPHIC RANGE.

The remains of Echinodermata are found in Mesozoic deposits at nearly all horizons and at widely separated localities but are much more numerous and characteristic in Cretaceous than in Triassic and Jurassic strata. In several of the Cretaceous formations they are among the most valuable diagnostic fossils, and at a few localities they occur in vast numbers.

Comparatively few Triassic forms have been found. The most common are crinoid stems representing the genera Isocrinus and Encrinus, the former appearing in the Lower Triassic of Idaho, the Middle Triassic of Nevada, and the Upper Triassic of California, and the latter being confined to the Upper Triassic of California. The echinoids are represented by two species of Cidaris, which are confined to the Upper Triassic of California. In addition to these a few indistinct casts, among them a small, poorly preserved starfish, which has been questionably assigned to the genus Aspidura, have been found in the Lower Triassic of Idaho.

The Jurassic echinoderms are somewhat more numerous and varied, although they form no considerable proportion of the known American fossil Echinodermata. The most common forms belong to the genus Pentacrinus, column joints having been found in Nebraska, South Dakota, Wyoming, Colorado, Idaho, Utah, and California. The asteroids are represented by both the Ophiuridæ and the Stelleridæ, specimens having been found in Wyoming, South Dakota, and Utah. The echinoids are much more fully represented than in the Triassic. Several genera have been recognized, among them Cidaris, Hemicidaris, Pseudodiadema, Stomechinus, Holectypus, and Pygurus. Most of the specimens are poorly preserved and are in few places numerous. The first four genera occur only in California, being found in both the Lower and Middle Jurassic. One species of Holectypus occurs in Texas and another in Montana. Pygurus has been found only in Texas.

The Cretaceous echinoderms are very numerous in certain areas. A great variety of types is represented and much of the material is splendidly preserved. Many of the species are narrowly limited in geologic range and are therefore important as type fossils.

The crinoids are represented by Uintacrinus, Marsupites, Pentacrinus, and Rhizocrinus, the first named having afforded a great number of remarkable specimens in the Niobrara chalk of Kansas. Springer has made this material the subject of an elaborate monograph, and most of the great museums of the world contain beautiful specimens from the now famous locality in Kansas.

The stelleroids contain representatives of both the Ophiuroidea and the Asteroidea, the genera Ophioglypha, Astropecten, Goniaster, Pentagonaster, and Pentaceros being found. The material comes from widely separated areas in New Jersey, Texas, and Wyoming.

The echinoids are very numerous, both the regular and irregular types being well represented. Both the Lower and Upper Cretaceous deposits of Texas contain many species and vast numbers of individuals at several horizons; and the Upper Cretaceous of the Atlantic and eastern Gulf coasts, particularly in New Jersey, North Carolina, Alabama, and Mississippi, although fully characterized by its echinoid fauna, affords many forms. The western interior and Pacific coast Cretaceous contains a much smaller representation of echinoid types.

Among the Lower Cretaceous genera represented, more particularly in Texas, are: Cidaris, Salenia, Hypodiadema, Goniopygus, Pseudodiadema, Diplopodia, Cyphosoma, Holectypus, Pyrina, Enallaster, and Hemiaster. Outside of Texas very few Lower Cretaceous echinoids have been recognized. The Horsetown formation of California contains a few forms.

The Upper Cretaceous of Texas contains a large echinoid fauna and some of the genera possess many species. They are: Cidaris, Leiocidaris, Leptarbacia, Orthopsis, Heterodiadema, Cottaldia, Diplopodia, Cyphosoma, Micropsis, Holectypus, Echinobrissus, Cassidulus, Ananchytes, Cardiaster, Holaster, and Hemiaster.

The Upper Cretaceous of the Atlantic and Gulf coasts has afforded representatives of the following genera: Cidaris, Salenia, Pseudodiadema, Coptosoma, Psammechinus, Echinobrissus, Trematopygus, Botriopygus, Cassidulus (many species of which have been recognized), Catopygus, Echinanthus, Ananchytes, Cardiaster, Hemiaster, and Linthia. Much the larger number of Atlantic coast forms have been found in the New Jersey Cretaceous, especially in the Vincentown sand of the Rancocas group, which is regarded as probably of Danian age. The western interior and Pacific coast areas contain few representatives of the echinoids, most of the species belonging to the genus Hemiaster.

The absence of species identical with those of other continents and particularly of Europe renders impossible a detailed correlation of American and foreign horizons on the basis of their echinoderm faunas. However, genera represented in the main divisions of the Mesozoic in America are with scarcely an exception similar to those typical of the same divisions elsewhere.

The accompanying tables show the stratigraphic positions of the more important American Mesozoic formations, the geologic distribution of the Mesozoic Echinodermata of the United States, and the stratigraphic distribution of the Cretaceous Echinodermata of Texas.

Relative stratigraphic positions of the more important American Mesozoic formations.

[Vertical parallel lines indicate formations which occur in separate areas and whose exact equivalence is not established.]

System.	Pacific border (California).	Western interior.	Texas.	Eastern Gulf area.	Southern Atlantic border.[a]	Northern Atlantic border.[b]	Europe.
Cretaceous.		Laramie				Manasquan Rancocas	Danian
		Montana {Fox Hills / Pierre}	Navarro	Ripley	Peedee	Monmouth	Senonian
			Taylor	Selma		Matawan	
	Chico	Colorado {Niobrara / Benton}	Austin				Turonian
			Eagle Ford	Eutaw	Black Creek	Magothy	
		Dakota	Woodbine	Tuscaloosa		Raritan	Cenomanian
		Fuson	Comanche series: Washita {Buda / Del Rio} Denison; Georgetown {Fort Worth / Preston}			Potomac: Patapsco	Albian Aptian
	Shasta: Horsetown		Comanche series: Fredericksburg {Edwards / Comanche Peak / Walnut}				
	Shasta: Knoxville	Lakota	Comanche series: Trinity {Paluxy / Glen Rose / Travis Peak}			Arundel	Barremian
				"Basal clays" = Patuxent (?)	Patuxent (?)	Patuxent	Neocomian
		Morrison	Malone				
Jurassic.	Mariposa Foreman Hinchman Bicknell	Sundance | Ellis | Twin Creek					Upper
	Mormon Thompson						Middle
	Hardgrave Trail						Lower
Triassic.	Brock | Swearinger Hosselkus	Star Peak.[c]				Newark	Upper
	Pit						Middle
		Thaynes					Lower.

[a] Includes North and South Carolina.

[b] Includes Virginia, Maryland, Delaware, and New Jersey.

[c] Star Peak is really a Pacific border formation.

Geologic distribution of the Mesozoic Echinodermata of the United States.

	Triassic.	Jurassic.	Lower Cretaceous.	Upper Cretaceous.
Crinoidea:				
Dicyclica—				
Inadunata—				
Dendrocrinoidea—				
Pentacrinidæ—				
Isocrinus smithi Clark		×		
Isocrinus californicus Clark		×		
Isocrinus sp		×		
Isocrinus knighti Springer			×	
Pentacrinus asteriscus Meek & Hayden			×	
Pentacrinus whitei Clark			×	
Pentacrinus shastensis Clark			×	
Pentacrinus tehamaensis Clark			×	×
Pentacrinus bryani Gabb				×
Encrinidæ—				
Encrinus hyatti Clark	×			
Uintacrinidæ—				
Uintacrinus socialis Grinnell				×
Marsupitidæ—				
Marsupites americanus Springer				×
Flexibilia—				
Pinnata—				
Bourguetiicrinidæ—				
Rhizocrinus alabamensis de Loriol				×
Rhizocrinus cylindricus Weller				×
Stelleroidea:				
Asteroidea—				
Phanerozonia—				
Astropectininæ—				
Astropecten (?) montanus Douglas				×
Pentagonasteridæ—				
Pentagonaster browni Weller				×
Atheneidæ—				
Goniaster mammillata Gabb				×
Pentacerotidæ—				
Pentaceros asperulus Clark				×
Cryptozonia—				
Asteriidæ—				
Asterias (?) dubium Whitfield		×		
Ophiuroidea—				
Zygophiuræ—				
Ophiolepididæ—				
Ophioglypha utahensis Clark		×		
Ophioglypha texana Clark				×
Ophioglypha bridgerensis (Meek)				×
Amphiuridæ—				
Aspidura (?) idahoensis Clark	×			
Echinoidea:				
Regularia endobranchiata—				
Cidaroidea—				
Cidaridæ—				
Cidaris shastensis Clark		×		
Cidaris dilleri Clark		×		
Cidaris californicus Clark			×	
Cidaris taylorensis Clark			×	
Cidaris plumasensis Clark			×	
Cidaris tehamaensis Clark			×	
Cidaris texanus Clark				×
Cidaris walcotti Clark				×
Cidaris splendens Morton				×
(?) Cidaris dixiensis Cragin				×
Cidaris nahalakensis de Loriol				×
Leiocidaris hemigranosus (Shumard)				×
Regularia ectobranchiata—				
Diademoidea—				
Calycina—				
Saleniidæ—				
Salenia texana Credner			×	×
Salenia tumidula Clark				×
Salenia bellula Clark				×
Arbacina—				
Hemicidaridæ—				
Hemicidaris intumescens Clark		×		
Hypodiadema elegans Clark			×	
Goniopygus zitteli Clark			×	
Leptarbacia argutus Clark				×
Diademina—				
Orthopsodæ—				
Orthopsis planulata Clark				×
Orthopsis occidentalis Cragin				×
Diadematidæ—				
Pseudodiadema emersoni Clark		×		
Pseudodiadema texanum (Roemer)				×
Pseudodiadema diatretum (Morton)				×
Heterodiadema ornatum Clark				×
Cottaldia rotula Clark				×
Hemipedina charltoni Cragin				×
Diplopodiidæ—				
Diplopodia taffi Cragin			×	
Diplopodia streeruvitzi Cragin				×
Pedinidæ—				
Stomechinus hyatti Clark		×		
Cyphosomatidæ—				
Cyphosoma hilli Clark				×
Cyphosoma texanum Roemer			×	
Cyphosoma volanum Cragin				×

Geologic distribution of the Mesozoic Echinodermata of the United States—Continued.

	Triassic.	Jurassic	Lower Cretaceous.	Upper Cretaceous.
Echinoidea—Continued.				
Regularia ectobranchiata—Continued.				
Diademoidea—Continued.				
Diademina—Continued.				
Cyphosomatidæ—Continued.				
Coptosoma speciosum Clark				
Coptosoma mortoni (de Loriol)				
Micropsis linearis Clark				
Echinina—				
Triplechinidæ—				
Psammechinus cingulatus Clark				×
Pedinopsis symmetrica (Cragin)				×
Pedinopsis ponderi Clark				×
Irregularia—				
Gnathostomata—				
Holectypina—				
Pygasteridæ—				
Holectypus pealei Clark				
Holectypus cragini Clark				
Holectypus planatus Roemer				
Clypeastrina—				
Clypeastridæ—				
Echinanthus mortonis (Michelin)				
? Scutellaster cretaceus Cragin				
Atelostomata—				
Asternata—				
Echinoneidæ—				
Pyrina parryi Hall				×
Nucleolitidæ—				
Botriopygus alabamensis Clark				×
Echinobrissus angustatus Clark				×
Echinobrissus expansus Clark				×
Echinobrissus texanus Clark				×
Trematopygus cruciferus (Morton)				×
Cassidulidæ—				
Pygurus sp				
Pygurus (?) geometricus (Morton)				×
Catopygus oviformis Conrad				×
Catopygus pusillus Clark				×
Catopygus williamsi Clark				×
Catopygus sp				×
Cassidulus florealis (Morton)				×
Cassidulus æquoreus Morton				×
Cassidulus microcoreus Gabb				×
Cassidulus subquadratus Conrad				×
Cassidulus subconcus Clark				×
Cassidulus porrectus Clark				×
Cassidulus stantoni Clark				×
Cassidulus intermedius Slocum				×
Cassidulus hemisphericus Slocum				×
Cassidulus conoideus Clark				×
Cassidulus abruptus Conrad				×
(?) Cassidulus subangulatus (Emmons)				×
Sternata—				
Echinocorythidæ—				
Ananchytes ovalis Clark				×
Ananchytes texana Cragin				×
Cardiaster cinctus (Morton)				×
Cardiaster smocki Clark				×
Cardiaster curtus Clark				×
Holaster simplex Shumard				×
Spatangidæ—				
Enallaster texanus (Roemer)				×
Enallaster obliquatus Clark				
Hemiaster elegans Shumard				×
Hemiaster whitei Clark				×
Hemiaster bexari Clark				×
Hemiaster comanchei Clark				
Hemiaster dalli Clark				×
Hemiaster calvini Clark				×
Hemiaster parastatus (Morton)				×
Hemiaster stella (Morton)				×
Hemiaster ungula (Morton)				×
Hemiaster texanus Roemer				×
Hemiaster humphreysanus Meek and Hayden				×
Hemiaster californicus Clark				×
Hemiaster beecheri Clark				×
Hemiaster lacunosus Slocum				×
Hemiaster kümmeli Clark				×
Hemiaster wetherbyi Clark				×
Linthia tumidula Clark				×
Linthia variabilis Slocum				×

Stratigraphic distribution of the Cretaceous Echinodermata of Texas.

	Trinity.	Fredericksburg.	Washita.	Austin.	Taylor.
Ophioglypha texana Clark			×		
Cidaris texanus Clark			×		
Cidaris dixiensis Cragin					×
Leiocidaris hemigranosus (Shumard)			×		
Salenia texana Credner		×	×		
Hypodiadema elegans Clark	×				
Goniopygus zittelli Clark		×			
Leptarbacia argutus Clark			×		
Orthopsis planulata Clark			×		
Orthopsis occidentalis Cragin			×		
Pseudodiadema texanum (Roemer)	×	×			
Heterodiadema ornatum Clark			×		
Cottaldia rotula Clark			×		
Hemipedina charltoni Cragin			×		
Diplopodia taffi Cragin		×			
Diplopodia steeruvitzi Cragin			×		
Cyposma hilli Clark				×	
Cyphosoma volanum Cragin		×			
Micropsis lineatus Clark			×		
Pedinopsis symmetrica (Cragin)			×		
Pedinopsis pondi Clark				×	
Holectypus planatus Roemer	×	×	×		
Pyrina parri Hall		×	×		
Echinobrissus augustatus Clark			×		
Echinobrissus texanus Clark				×	
Ananchytes texana Cragin				×	
Holaster simplex Shumard			×		
Enallaster texanus (Roemer)	×	×	×		
Enallaster obliquatus Clark	×				
Hemiaster elegans Shumard			×		
Hemiaster whitei Clark		×	×		
Hemiaster bexari Clark			×		
Hemiaster comanchei Clark	×				
Hemiaster dalli Clark			×		
Hemiaster cavini Clark			×		
Hemiaster texanus Roemer				×	

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NOTE.—A number of contributions have appeared during the progress of this report through the press, the results of which can not be fully incorporated in the following pages, although footnotes concerning some of them have been inserted. Among the more important of these publications are:

JACKSON, R. T., Phylogeny of the Echini, with a revision of Paleozoic species: Boston Soc. Nat. Hist. Mem., vol. 7, 491 pp., 76 pls., 258 figs., 1912.

Jackson proposes the generic name Centrechinus to replace Diadema, thus changing the names of family and order to which the genus belongs.

SMITH, J. P., The Middle Triassic marine invertebrate faunas of North America: U. S. Geol. Survey Prof. Paper 83, 254 pp., 99 pls., 1914.

Smith refers to Pentacrinus cf. *P. asteriscus* Meek and Hayden, in material from the Pit shale of California.

TRIASSIC ECHINODERMATA.

Class CRINOIDEA.

Subclass DICYCLICA.

Order INADUNATA.

Suborder DENDROCRINOIDEA.

Family PENTACRINIDÆ.

Genus ISOCRINUS von Meyer.

Isocrinus smithi Clark, n. sp.

Plate I, figures 1a-b.

Determinative characters.—Column composed of small moderately thick pentagonal joints, with sharp reentering angles on the large specimens. Column perforated by small canal.

Dimensions.—Column: Diameter of joint ½ to 2 millimeters; length of joint ⅓ to 1 millimeter.

Description.—The joints are generally separated and more or less weathered, being found in great numbers on many leached surfaces of limestone. The largest and best-preserved specimens are moderately thick and show sharp reentering angles. The crenulated ridges are generally so badly weathered that their characters are obscured, but they are broadly petaloid with rather sharp angles at their outer extremities. All the Lower Triassic forms are assigned to this species. Some minor differences appear among the specimens examined, however, and more than one species may be represented.

Locality.—One mile west of Paris, Bear Lake County, Idaho.

Geologic horizon.—Columbites zone, Thaynes limestone, Lower Triassic, 150 feet above strata with Meekocēras fauna, but below beds containing typical Lower Triassic forms.

Collections.—U. S. National Museum (31184); Leland Stanford Junior University.

Isocrinus californicus Clark, n. sp.

Plate I, figures 2a–c

Determinative characters.—Column composed of medium-sized rather thin pentagonal joints, with sharp reentering angles. The crenulated ridges are rather narrowly petaloid, and each area is sharply terminated at its outer extremity. Column perforated by large canal.

Dimensions.—Column: Diameter of joint 2 to 5 millimeters; length of joint ½ to 1 millimeter.

Description.—Several specimens of isolated column joints of Isocrinus from the Upper Triassic rocks of California, which may or may not belong to a single species, have been examined by the author. Differences in the size of the joints and the sharpness of the reentering angles appear, but they may be due to difference in age of the individuals represented or by the different positions of the joints on the stem. In the absence of more satisfactory criteria, therefore, all the Upper Triassic Pentacrini examined have been referred to this species. The majority of specimens studied are not of large size, although considerably larger than *I. smithi* of the Lower Triassic. Most of them show deep reentering angles. The crenulated ridges are obscure in many specimens, but where well preserved are rather narrowly petaloid, and each area is sharply terminated at its outer extremity. A large well-marked canal perforates the column.

Locality.—Two and one-half miles west of Round Mountain, Shasta County (type), and at Rush Creek, Plumas County, Cal.

Geologic horizon.—"Cedar formation," Upper Triassic.

Collections.—U. S. National Museum (31185); Leland Stanford Junior University.

Isocrinus sp.

Pentacrinus asteriscus (?) Hall and Whitfield, 1877, U. S. Geol. Expl. 40th Par. Final Rept. vol. 4, pp. 280, 281, Pl. VI, fig. 16.

Hall and Whitfield examined several column joints of supposed Pentacrinus collected by Arnold Hague of the 40th Parallel Survey "in limestone of supposed Triassic age, associated with *Spiriferina homfrayi* and *Terebratula humboldtensis* Gabb, near Dun Glen Pass, Pahute Range, Nevada," which they doubtfully referred to *P. asteriscus* Meek and Hayden of the Jurassic of the Rocky Mountain region. They note certain differences "in the more obtuse points of the star, and the filling up of the angles between the points, and also in the broader form of the elliptical figures on the articulating surfaces of the disks." They state that although these features are not constant the form is larger than *P. asteriscus*, and that better material would doubtless show it to be another species. It is evident that this form can not be safely referred to the Jurassic species *P. asteriscus*, but as the author has not had access to further material it is simply referred to the genus Isocrinus without specific description. The limestones at Dun Glen Pass were correlated with the base of the Star Peak formation, and more recent work has confirmed this determination.[1] The Star Peak formation is of both Middle and Upper Triassic age.

Locality.—Dun Glen Pass, Pahute Range, Nevada.

Geologic horizon.—Limestone of Dun Glen Pass, Middle Triassic.

Collection.—U. S. National Museum.

Family ENCRINIDÆ.

Genus ENCRINUS C. F. Schulze.

Encrinus hyatti Clark, n. sp.

Plate I, figures 3a–b.

Determinative characters.—Column composed of large, thin, round to oval joints. Surfaces of joints covered with fine, bifurcating striations, producing a close suture. Column perforated with canal of rather small size.

Dimensions.—Column: Diameter of joint 5 to 10 millimeters; length of joint 1 to 3 millimeters.

Description.—Several specimens of casts of the column joints of Encrinus have been examined by the author from a single Upper Triassic locality in California. The column itself is wanting in every specimen, but the cast of the "close surface" is very perfect, much more so than the cast of the outer surface, which in all specimens has lost its distinctive features. Most of the casts show a somewhat oval outline, which may be due to compression, as the stems of most of the species belonging to this genus are round.

The joints surpass considerably in size those of any other crinoid form in the American Mesozoic. The round to oval shape of the "close surface" of the specimens and the fine bifurcating striations thereon are highly distinctive, enabling the relations of the form to be readily determined even in small fragments. All the specimens evidently belong to the same species. A rather small canal is present.

Locality.—Oscar tunnel, 2½ miles southeast of Longville, Plumas County, Cal.

Geologic horizon.—"Cedar formation," Upper Triassic.

Collection.—U. S. National Museum (31186).

[1] During the progress of this report through the press a paper by J. P. Smith (The Middle Triassic marine invertebrate faunas of North America: U. S. Geol. Survey Prof. Paper 83, 1914) has appeared, in which he says (p. 148): "A species identical with that of Dun Glen, Nev., occurs in the Pit shale of California, associated with a poor fauna characteristic of the Middle Triassic." It is referred to Pentacrinus cf. *P. asteriscus* Meek and Hayden.

Class STELLEROIDEA.

Subclass OPHIUROIDEA.

Order ZYGOPHIURÆ.

Family AMPHIURIDÆ.

Genus ASPIDURA Agassiz.

ASPIDURA (?) IDAHOENSIS Clark, n. sp.

Plate I, figure 4.

Determinative characters.—Casts of small forms, with short arms. Very poorly preserved.

Dimensions.—Diameter of disk 5 to 7 millimeters; length of arms 10 to 25 millimeters.

Description.—Three individuals of this species, all in a very imperfect state of preservation, have been examined. They occur as partial casts of the disk and rays. The characteristics of none of the plates can be seen. The general outline of the disk and rays remains constant in all the specimens, which evidently belong to the same species.

Locality.—One and one-half miles west of Paris, in the first canyon north of Paris Canyon, Bear County, Idaho.

Geologic horizon.—Thaynes limestone, Lower Triassic.

Collection.—U. S. National Museum (31187).

Class ECHINOIDEA.

Subclass REGULARIA ENDOBRANCHIATA.

Order CIDAROIDEA.

Family CIDARIDÆ.

Genus CIDARIS Leske.

CIDARIS SHASTENSIS Clark, n. sp.

Plate I, figure 5.

Determinative characters.—Test apparently large. Interambulacral areas wide. Tubercles large, circular, with depressed areolas; miliary space large.

Dimensions.—Width of fragment 10 millimeters; height of fragment 6 millimeters.

Description.—The single fragmentary interambulacral plate found indicates that this species possessed a test of considerable size. The interambulacral areas are wide, the tubercles large, circular, and with depressed areolas. The miliary space is large. The plate is probably from near the ambitus. The broken tubercle renders it impossible to say whether the mamelon was perforated or not. There is no trace of the plates of the ambulacral area.

Related forms.—Species is shown by the wide miliary space to be quite distinct from *C. dilleri*. It is evidently a new species.

Locality.—Two and one-half miles west of Round Mountain, Shasta County, Cal.

Geologic horizon.—"Cedar formation," Upper Triassic.

Collection.—U. S. National Museum (31188).

CIDARIS DILLERI Clark, n. sp.

Plate I, figure 6.

Determinative characters.—Test apparently of medium size; ambulacral areas narrow, flexuous, with two rows of granules between the poriferous avenues; interambulacral areas of moderate width. Tubercles of medium size with oval areolas; boss crenulated; mamelon perforated; miliary space narrow.

Dimensions.—Test: probable diameter about 35 millimeters; probable height about 25 millimeters: size of interambulacral plate near ambitus: Width 8 millimeters; height 6 millimeters.

Description.—The portion of the test studied in the single specimen of this species thus far found is in the form of a cast of the exterior of three interambulacral plates with their adjacent ambulacral plates on either side. The casts afford a very perfect mold of the more important features of these plates, which are apparently below the ambitus, in this respect differing from the specimen of *C. shastensis*, which comes apparently from nearer the ambitus.

The test was probably of medium size. The ambulacral areas are narrow, strongly flexuous, with two rows of small granules between the poriferous avenues. The interambulacral areas are of moderate width, being largely occupied by the tubercles, which are of medium size. The areolas are oval, the boss crenulated and the mamelon perforated. The miliary space is very narrow, very few granules being found on the area.

Related forms.—Form is shown by its small miliary areas to be quite distinct from *C. shastensis*. It is evidently a distinct species.

Locality.—Two and a half miles west of Round Mountain, Shasta County, Cal.

Geologic horizon.—"Cedar formation," Upper Triassic.

Collection.—U. S. National Museum (31189).

JURASSIC ECHINODERMATA.

Class CRINOIDEA.

Subclass DICYCLICA.

Order INADUNATA.

Suborder DENDROCRINOIDEA.

Family PENTACRINIDÆ.

Genus ISOCRINUS von Meyer.

Isocrinus knighti Springer.

Plate II, figures 1–13; Plate III, figures 1a–d.

?*Pentacrinites asteriscus* Meek and Hayden, 1865, Paleontology Upper Missouri: Smithsonian Contr., vol. 14 (172), p. 67, text fig. (not Pl. III, figs. 2a-b).
Pentacrinus asteriscus Knight, 1900, Geol. Soc. America Bull., vol. 11, p. 386.
?*Pentacrinus asteriscus* Logan, 1900, Kansas Univ. Quart., vol. 9, p. 119, Pl. XXV, figs. 4–7.
Isocrinus knighti Springer, 1909, U. S. Nat. Mus. Proc., vol. 36, pp. 179–190, Pl. IV, figs. 1–13.

Determinative characters.—Springer describes the species as follows:

Specimens of moderate size.

Stem smooth, long, slightly increasing in diameter distally; pentagonal with straight sides, except at the proximal end, where for the first few immature internodes the younger joints are stellate. Internodals about 14, but varying from 12 to 17 in the mature parts; distinctly crenulated at the margins; nodals not enlarged, scarcely distinguishable from the others except by the cirrus sockets; these are rather shallow, not extending to the hypozygal, or infranodal joint, but usually encroaching upon the supranodal, in which case the apposed faces of these two joints are more or less indented, producing a marked stellate outline. Conformably to this structure the cirri are directed upward. Interarticular pores extending to the fifth internode. Cirri in whorls of five; round, long, and slender, composed of 40 joints or more; the proximal ones relatively short and broad—about one-third as long as wide—tapering rapidly to about half their breadth, and doubling in length in the first 8 or 10 joints, beyond which they continue uniformly about as long as wide to the end; terminal claw not preserved. Angles of stem interradial; cirri radial; axial canal in stem small, obtusely pentagonal, and apparently interradial in position.

Cup forming a low cone, without any downward projection or basals or radials. Infrabasals well defined, filling half the diameter of the column facet and entirely covered by the proximal columnal. Basals large, smooth, visible in pentagonal outline, and in full contact exteriorly by their lateral faces; they form a closed ring, not protuberant but flush with the plane of the radials, and about equal to them in height. Radials forming also a ring continuous with basals. Primibrachs two, united by articulation apparently bifascial. Arms simple, or bifurcating once from the sixteenth to the thirtieth IIBr, thus varying from 10 to 20; they are long, slender, with strongly oblique articulating faces, and they extend to upward of 90 brachials. Syzygies at IIBr 3 + 4, and beyond throughout the arm at intervals of about 5 to 10 brachials. Pinnules long, rounded, composed of elongate joints, 15 or more in the distal pinnules, but the number in the proximal ones not observable. Disk unknown.

Dimensions.—Height of crown 65 millimeters; length of cirrus of 40 joints 32 millimeters; length of longest stem preserved 140 millimeters; diameter of stem at second internode 2 millimeters; diameter of stem at tenth internode 2.5 millimeters.

Description.—The first complete crown of this species was obtained by the late W. C. Knight, of the University of Wyoming, in 1899, in the course of his investigations of the Morrison formation near Medicine Bow, Wyo. He found one very complete specimen and numerous stems and fragments of arms on several small slabs of argillaceous limestone that lay in the débris. He referred the crown to *Pentacrinus asteriscus*. Some additional material obtained the following year has afforded several additional crowns. All the specimens were finally placed for study in the hands of Springer, who finds reasons for believing that the form belongs to Isocrinus and not Pentacrinus.[1]

[1] A new American Jurassic crinoid: U. S. Nat. Mus. Proc., vol. 36, pp. 179–190, Pl. IV, 1909.

Springer in describing this species makes the following interesting comparison with recent species:

The stem has a considerable resemblance to that of *I. decorus*, except in the disposition of the cirri. It must have been quite long, as the longest portion, preserved to a distance of 140 millimeters, shows little sign of any rounding. It is rather more pentagonal for equivalent distances. The cirri are very long and slender; the taper near the base from short and wide joints to long, narrow, and equal ones is quite marked. The most perfect one has 44 joints, and this was probably near the maximum. The interesting thing about the cirri, however, is the fact that they are directed upward instead of downward or outward. In consequence the sockets do not extend to the infranodal (hypozygal) joint, but slope upward toward the supranodal, the lower margin of which is often incised by them. This is more or less the case in the genus Metacrinus, but is not usual in the recent species of Isocrinus, most of which have the cirri directed downward, though in some, as *I. asteria* and *I. wyville-thomsoni*, the socket is confined to the nodal joint, and the cirri are given off about horizontally.

The basals, as shown by the five specimens figured and three others, are quite uniform in their form and proportions. They form with the radials a low funnel, with smooth or slightly rounded sides, and without protuberance or projection of any kind. They are connected exteriorly by their lateral faces, giving a pentagonal outline and forming a closed ring [Pl. II, fig. 3a], as in the type for which Forbes proposed the genus Cainocrinus, instead of appearing as mere triangular points separated from each other by the radials and tending more or less to project downward over the proximal column joints, as in more recent species.

The bifurcation of the arms so far beyond the axillary IBr is an unusual feature, occurring in the largest specimen at the twenty-seventh to the thirtieth brachial [Pl.II, fig. 1], and in other specimens from the sixteenth to the twenty-third. I know of no pentacrinoid in which arm division takes place so high up; nor in fact any inadunate crinoid, the nearest approach to it being found in the Carboniferous genus Poteriocrinus. There is little tendency of the arms to spread out, but they are long and slender, tending rather to lie in a bundle. The general aspect of calyx and arms is somewhat like that of *I. naresianus*, which it also resembles in the number and regularity of the syzygies, which is unusual in the Pentacrinidæ. I can trace them in two arms of specimen A [Pl. II, fig. 1] part way, and in one to the end, and can distinguish them in the distal portion of some other arms. Beginning at IIBr 3 + 4, they occur at intervals of mostly about 10 brachials, but sometimes 4, 5, or 6. I give a figure of the pair next to the last, being about brachials 79 + 80 of that arm [Pl. II, fig. 1a].

Related forms.—Springer states that the stem joints of *I. knighti* —

are uniformly different from the much larger ones on which *P. asteriscus* was founded, and from the Utah specimen referred by Dr. White to *P. asteriscus* [1] but afterwards separated from it by Dr. W. B. Clark under the name *Pentacrinus whitei*, because of its alternating joints. Clark's camparison was made chiefly with the Red Buttes specimen of *P. asteriscus* (?), but the separation is doubtless well founded, nevertheless, as the character on which he bases it is clear in his specimen, and cannot be shown in the type of *P. asteriscus*. The difference between the stem of our species and that of *P. whitei* is similar to that between the recent *I. decorus* and *I. parræ*, which is fairly constant.

The most nearly related European species that I know of is de Loriol's "*Pentacrinus*" *beaugrandi* from the Upper Jurassic, Portlandian stage, near Boulogne-sur-Mer, France.[2] This was the only Crinoid known to the author from the Portlandian stage, and it is the species which he originally proposed to separate from the other Pentacrinidæ on account of having a closed ring of basals, under the name Picteticrinus. In this he found himself anticipated by the Cainocrinus of Forbes, and in the work last cited, page 281, he abandoned the distinction, and referred the species to Pentacrinus (sensu P. H. C.). It has similar large basals, but the arms branch lower down, the stem is more sharply stellate in corresponding portions, and the cirri much more delicate. The stem is preserved to the fourth internode, which has 8 internodals, whereas ours has 14 at the same stage.

Pentacrinus (*Cainocrinus*) *andreæ* Desor [3] is similar to the French species, but with shorter basals and shorter internodes.

Localities.—Medicine Bow (type) and Red Buttes, Wyo.
Geologic horizon.—Sundance formation (Shirley stage of Knight), Upper Jurassic.
Collection.—U. S. National Museum (682).

Genus PENTACRINUS Blumenbach.

PENTACRINUS ASTERISCUS Meek and Hayden.

Plate III, figure 2.

Pentacrinus asteriscus Meek and Hayden, 1858, Acad. Nat. Sci. Philadelphia Proc., vol. 10, p. 49.
Pentacrinus asteriscus Meek and Hayden, 1860, Acad. Nat. Sci. Philadelphia Proc., vol. 12, p. 419.
Pentacrinus asteriscus Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 27.
Pentacrinites asteriscus Meek and Hayden, 1865, Paleontology Upper Missouri, Smithsonian Contr., vol. 14 (172), p. 67, Pl. III, figs. 2a, 2b.

[1] U. S. Geol. Survey Bull. 97, p. 27, 1893.
[2] Mon. étage Jur. Boulogne-sur-Mer, p. 298, Pl. XXVI, figs. 23–25, 1875; Paléontologie française, Crinoïdes, vol. 11, pt. 2, p. 278, Pl. CLXXXI, figs. 1–3.
[3] De Loriol, Crin. foss. de la Suisse, p. 112.

Pentacrinites asteriscus Whitfield, 1880, Paleontology of Black Hills of Dakota: U. S. Geog. and Geol. Survey Rocky Mtn. Region, p. 345, Pl. III, figs. 1, 2.
Pentacrinus asteriscus Peale, 1880, U. S. Geol. and Geog. Survey Terr. Bull., vol. 5, No. 1, p. 120.
Pentacrinus asteriscus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Pentacrinus asteriscus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 26, 27, Pl. II, figs. 2a–d.
Pentacrinus asteriscus Weed and Pirsson, 1898, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 478.
Pentacrinus asteriscus Stanton, 1899, U. S. Geol. Survey Mon., vol. 32, pt. 2, p. 608.
Pentacrinus asteriscus Knight, 1900, Wyoming Exper. Sta. Bull. 45, Pl. IV, fig. 2.
Pentacrinus asteriscus Darton, 1901, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 4, p. 521.

Determinative characters.—Columns composed of medium-sized pentagonal joints with moderately deep reentering angles; crenulated ridge of suture strongly petaloidal; column perforated by canal of medium size.

Dimensions.—Column: Diameter of joint 2 to 5 millimeters.

Description.—First described by Meek and Hayden from several column joints found in the Black Hills. When they redescribed and figured the species in 1865 they combined with the earlier forms certain smaller column joints found at Red Buttes on North Platte River, figures of which were given in the text, but these have been recently doubtfully referred by Springer to *Isocrinus knighti*. Meek and Hayden in this later publication state that their "description applies more particularly to the largest-sized specimens" from the Black Hills and that the two figures on their Plate III represent these forms, which must therefore be regarded as the type of the species.

Many similar isolated column joints have been found widely scattered throughout the Rocky Mountain region by different geologists and most of them are regarded by the author as belonging to this species. Since it has been clearly demonstrated that the column joints vary in the different portions of the stem of nearly all crinoids it is evident that several different species and possibly even different genera may be represented among these forms.

The specimens referred to this species are of moderate size, clearly pentagonal, and with moderately deep reentering angles, the points of the rays being sharp, and the suture joints apparently uniting to form a compact column.

Hall and Whitfield referred doubtfully to *Pentacrinites asteriscus* Meek and Hayden certain specimens collected by Hayden in Nevada from "limestones of supposed Triassic age." There is much doubt as to this form, but it evidently does not belong to *P. asteriscus*.

Related forms.—The species presents some points of difference from *P. whitei*, which has been generally regarded as belonging to it. Its column joints are generally somewhat smaller, are not alternating, do not have as deep reentering angles, and its rays are somewhat sharper. The crenulation of its petaloid area is also somewhat different. This species is somewhat similar to *Pentacrinus shastensis* of the Pacific coast, but the latter is of slightly different form and generally has shallower reentering angles.

Localities.—South and southwest base of Black Hills, South Dakota (type), and Red Buttes, Wyo.; South Dakota, Idaho, and Colorado (Meek); southeastern Idaho and western Wyoming (Peale); Black Hills, South Dakota (Whitfield); Sundance formation (Upper Jurassic), Black Hills, South Dakota (Darton).

Geologic horizon.—Jurassic.

Collection.—U. S. National Museum (220); University of Kansas.

Pentacrinus whitei Clark.

Plate III, figures 3a–c.

Pentacrinus asteriscus White, 1875, U. S. Geog. Surveys W. 100th Mer. Rept., vol. 4, pt. 1, p. 162, Pl. XIII, figs. 6a–b.
Pentacrinus whitei Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Pentacrinus whitei Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 27, 28, Pl. III, figs. 2a–d.
Pentacrinus whitei Springer, 1909, U. S. Nat. Mus. Proc., vol. 36, p. 188.

Determinative characters.—Column composed of large, thin, alternating, pentagonal joints with deep reentering angles; crenulated ridges of suture with strong pentaloid arrangement; column perforated by canal of medium size.

Dimensions.—Column: Diameter of joint 5 to 8 millimeters; height of joint 1 to 1½ millimeters.

Description.—C. A. White describes and figures certain specimens as *Pentacrinus asteriscus* Meek and Hayden that evidently belong to a different species. Springer, who has examined the same material, is likewise of the opinion that the separation of the forms from *P. asteriscus* is well founded. The name *P. whitei* was proposed by the author in honor of the distinguished geologist who did so much to advance our knowledge of western American Mesozoic geology and paleontology.

The column joints are relatively thin, with rounded edges, and alternate with each other, so that the column does not appear compactly formed when viewed from the side. A distinct petaloid arrangement of the crenulated ridge is exhibited in all the forms.

Related forms.—The species is apparently closely related to *P. asteriscus*, from which it is separated by its generally larger alternating joints, deeper reentering angles, and less compact column.

Localities.—Salt Creek (type) and Diamond Valley, Utah (White).

Geologic horizon.—Jurassic.

Collection.—U. S. National Museum (8588).

Pentacrinus shastensis Clark, n. sp.

Plate III, figure 4.

Determinative characters.—Column composed of rather large pentagonal joints, with prominent reentering angles. The crenulated ridges of the suture have a rounded petaloid arrangement. Column perforated by a rather large canal.

Dimensions.—Column: Diameter of joint 6 to 9 millimeters; thickness of joint 1 to 1½ millimeters.

Description.—A number of casts of column joints of a Pentacrinus of medium size have been found in a very compact sandstone. They show very clearly the shape and exterior markings of the joints, which have very pronounced reentering angles and sharp long rays. In one of the best preserved specimens the crenulated edges of the suture present a prominent petaloid arrangement. This is not distinguishable in most of the specimens, which are too poorly preserved to show the finer details. Two of the specimens are casts of several combined joints in which the side characters of the column are clearly shown. The column is perforated by a rather large canal.

Related forms.—The species is somewhat similar to *P. asteriscus* Meek and Hayden, but is larger and of somewhat different form.

Localities.—One-half mile north of Holcombs stage station, 4 miles north of Buzzards Roost, and about 2½ miles west of Buzzards Roost (type), Shasta County, Cal.

Geologic horizon.—Jurassic.

Collection.—U. S. National Museum (31190).

Class STELLEROIDEA.

Subclass ASTEROIDEA.

Order CRYPTOZONIA.

Family ASTERIIDÆ.

Genus ASTERIAS Linnæus.

Asterias? dubium Whitfield.

Plate III, figure 6.

Asterias? dubium Whitfield, 1877, Preliminary report on the paleontology of the Black Hills, p. 15.
Asterias? dubium Whitfield, 1880, Paleontology of the Black Hills of Dakota, pp. 344, 345, Pl. III, fig. 3.
Asterias dubium Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Asterias? dubium Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 31, 32, Pl. V, fig. 2.
Asterias dubium Logan, 1900, Kansas Univ. Quart., vol. 9, pp. 130, 131, Pl. XXV, fig. 4.

Determinative characters.—Imperfectly preserved forms of small size, with slender flexuous arms, apparently covered superiorly with longitudinal rows of plates.

Dimensions.—Diameter of disk 10 to 12 millimeters; length of arms 15 to 28 millimeters.

Description.—This interesting but doubtful form is thus characterized by Whitfield:

> The specimens are not in condition to afford a full description of their specific characters. They are of small size, the rays being from three-fourths of an inch to 1¼ inches long, measuring from the center of the body. The rays are slender and flexuous, most of them being more or less curved in their direction and elevated along the middle, as shown on a gutta-percha cast taken in a natural mold of a group of three individuals. The upper surface is subangular, and in structure they are apparently composed of small uniform plates, placed in longitudinal rows. The center of the body or disk is marked by an obscurely pentangular depression on the upper surface. None of the specimens show the under side of the body or rays, so that the characters of these parts are entirely unknown.
>
> The species appears to have been somewhat abundant, judging from the condition in which they are grouped on the sandstone, and, although the specimens are obscure and too imperfect for positive determination and description, it has been thought best to designate them by names, as they will undoubtedly prove a characteristic form over a certain region and of a limited horizon. The sandstone is marked by the layers in which they are found by ripple or wave marks, having a width of about 3 inches, and indicates a near proximity to a shore line over the area where they were obtained, and that the individuals are probably stranded specimens. A single very imperfect impression of a lamellibranchiate shell is seen on the same fragments of rock, but too imperfect for determination.

Related forms.—This doubtful species scarcely admits of comparison with other forms. There is nothing from American Jurassic strata with which it can be closely associated.

Localities.—East side of Spearfish Creek near its junction with the Redwater, Black Hills, South Dakota (type); Freezeout Hills, Wyoming (Logan).

Geologic horizon.—In red sandstones of Jurassic age 70 feet above the "Red Beds" (Whitfield type); in a thin stratum of sandstone in the Jurassic bluish shale, No. 15 of the section (Logan), Jurassic.

Collections.—U. S. National Museum (325); Kansas University Museum.

Subclass OPHIUROIDEA.

Order ZYGOPHIURÆ.

Family OPHIOLEPIDIDÆ.

Genus OPHIOGLYPHA Lyman.

OPHIOGLYPHA UTAHENSIS Clark, n. sp.

Plate III, figure 5.

Determinative characters.—Dorsal or aboral surface of disk composed of numerous small imbricating plates with five pairs of "radial shields." Dorsal arm plates wider than high near the disk, gradually becoming longer toward the extremity of the arms. Narrow lateral arm plates shown on several of the arms.

Dimensions.—Diameter of disk 8 millimeters; length of arm 10 millimeters (not entire); width of arm near disk 1½ millimeters.

Description.—The only specimen of this species contains two individuals on the same slab together with a few fragments of arm plates. The aboral surface of the disk of one individual and several of the arms are in a good state of preservation. The surface of the disk is covered with a very large number of nearly equal sized imbricating plates of rounded form with the exception of the "radial shields," which are larger and elongate and stand in pairs at the head of the arms. The arms are long, but all the outer extremities are broken, so that the full length can not be determined. The dorsal arm plates are wider than high near the disk, but gradually lengthen as the distance from the disk increases until they become longer than wide. The lateral arm plates are preserved in places and appear as narrow plates more or less detached from the arms. The spines are not clearly shown.

Locality.—San Rafael River 10 miles below Castledale, Utah.

Geologic horizon.—Jurassic.

Collection.—U. S. National Museum (22839).

Class ECHINOIDEA.

Subclass REGULARIA ENDOBRANCHIATA.

Order CIDAROIDEA.

Family CIDARIDÆ.

Genus CIDARIS Leske.

Cidaris californicus Clark.

Plate IV, figures 1a–c.

Cidaris californicus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Cidaris californicus Clark, 1893, U. S. Geol. Survey Bull. 97, p. 36, Pl. VI, figs. 1a–b.

Determinative characters.—Test unknown. Spines large, club-shaped, with rows of large granules that coalesce to form longitudinal ridges which extend from neck to point of spine.

Dimensions.—Largest spine: Length 22 millimeters; breadth in thickest part 5 millimeters.

Description.—This species is based on detached spines, four or five specimens of which are found in material from Taylorsville, Cal. They are distinctive in every way and can not be mistaken, even in fragments. The specimens examined are casts but are so well preserved that impressions in gutta-percha, from which the drawings were made, show the characters completely. Each spine has a short narrow neck, beyond which it rapidly increases in size so as to give a club-shaped outline to the middle and upper portions. Rows of longitudinal granules cover the surface from the neck to the point of the spine, presenting the appearance of long serrated ridges.

Related forms.—Separated from *C. taylorensis* by its club-shaped form and surface characters.

Locality.—Taylorsville, Plumas County, Cal.

Geologic horizon.—Mormon sandstone, Middle Jurassic.

Collection.—U. S. National Museum (30184).

Cidaris taylorensis Clark.

Plate IV, figures 2a–b.

Cidaris taylorensis Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Cidaris taylorensis Clark, 1893, U. S. Geol. Survey Bull. 97, p. 35, Pl. VI, figs. 2a–b.

Determinative characters.—Test small. Interambulacra wide. Tubercles large, with circular areolas, much depressed marginally; boss crenulated; mamelon perforated. Miliary space narrow. Spines long, cylindrical, covered with small granules arranged in longitudinal rows.

Dimensions.—Test small but undetermined. Largest spine: Length 30 millimeters (?); width in broadest portion 5 millimeters.

Description.—The fragments of this form, although they permit determination of but few of the important characters, warrant specific description from the fact that they are totally distinct from the only other representative of Cidaris from the Jurassic rocks of America. The small fragments of the interambulacrum and the spine occur together and doubtless formed part of the same individual. The interambulacral plates, of which only portions are preserved on the specimen figured, indicate a form of no great size. The tubercles are large, with depressed areolas surrounded by a circle of large granules. The boss is crenulated and the mamelon perforated. The miliary space is apparently narrow, the tubercles of adjacent plates in the same column being nearly confluent.

The spine is long, gently tapering toward the base in the portion preserved, and covered with longitudinal rows of small granules.

Related forms.—As the Jurassic strata of North America afford few fossil Echinodermata as compared with the Cretaceous, there are not many American types with which the present form

may be compared. *C. californicus* is not known by its test and comparisons are limited to the spines. In *C. taylorensis* the spines are long and cylindrical, while in *C. californicus* they are short and thick set, and have a totally different surface decoration. *C. taylorensis* differs from *C. plumasensis* in its smaller miliary space and circular areolas.

Locality.—Taylorsville, Plumas County, Cal.

Geologic horizon.—Hardgrave sandstone, Lower Jurassic.

Collection.—U. S. National Museum (30183).

Cidaris plumasensis Clark, n. sp.

Plate IV, figure 3.

Determinative characters.—Test medium size. Ambulacra narrow. Interambulacra wide. Tubercles large with oval depressed areolas, crenulated boss, and perforated mamelon. Miliary space covered with coarse granules.

Dimensions.—Height of largest ambulacral plate 10 millimeters; width 14 millimeters.

Description.—Fragments of casts of the test of this species are found on a single slab of sandstone. The most perfect impression is of three interambulacral plates with adjacent ambulacral plates. It is evidently part of the test of a form of medium size. The ambulacra are narrow but the impression of the plates is obscure. The interambulacral plates are much better preserved and show large tubercles with oval areolas, somewhat depressed. The boss is crenulated and the mamelon perforated. The miliary space is rather wide and is covered with coarse granules.

Locality.—Taylorsville, Plumas County, Cal.

Geologic horizon.—Hardgrave sandstone, Lower Jurassic.

Collection.—U. S. National Museum (31191).

Subclass REGULARIA ECTOBRANCHIATA.

Order DIADEMOIDEA.

Suborder ARBACINA.

Family HEMICIDARIDÆ.

Genus HEMICIDARIS Agassiz.

Hemicidaris intumescens Clark.

Plate IV, figures 4a–i.

Hemicidaris intumescens Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Hemicidaris intumescens Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 44, 45, Pl. XII, figs. 1a–i.

Determinative characters.—Test spheroidal, upper surface inflated, lower surface flat. Ambulacra moderately broad, increasing in width from the apical system to the peristome. The tubercles at the peristome are nearly equal in size to those of the interambulacral areas, but become greatly reduced in passing from the ambitus to the apical system. Interambulacra rather wide, with two rows of large tubercles. Miliary space wide, covered with numerous granules. Peristome moderately wide, with deep incisions.

Dimensions.—Diameter 18 millimeters; height 12 millimeters.

Description.—The very perfectly preserved molds of the species permit the taking in gutta-percha of all the details of form and structure. As the only representative of the genus in American deposits it possesses considerable interest. The test is of moderate size, with a convex and slightly inflated upper surface and nearly flat lower surface. The slightly flexuous ambulacra broaden from the region of the apical disk toward the ambitus and slightly contract again before the peristome is reached. The tubercles are prominent in the lower part of the column, where several pairs attain a size nearly equal to those of the interambulacra. Minute perforated granules succeed them above and continue as a double row to the apical system. The

poriferous zones are slightly flexuous, and the small pores are uniserially arranged, although somewhat increased in the vicinity of the peristome.

The interambulacra are three to four times the width of the ambulacra at the ambitus. The two rows of medium-sized tubercles occupy the center of the plates; the areola is circular and slightly elevated; the boss deeply crenulated, and the mamelon distinctly perforated. There are about eight primary tubercles in each row. The apical system is rather large, although not sufficiently well preserved to admit of a determination of the individual plates.

The peristome is small and occupies scarcely one-half of the diameter of the test. It is deeply notched, the lobes being nearly equal in size.

Related forms.—The present species of Hemicidaris is the only representative of the genus known from American deposits. A comparison with European species fails to identify it with any described form.

Locality.—Taylorsville, Plumas County, Cal.

Geologic horizon.—Mormon sandstone, Middle Jurassic.

Collection.—U. S. National Museum (30187 and 30188).

Suborder DIADEMINA.

Family DIADEMATIDÆ.

Genus PSEUDODIADEMA Desor.

PSEUDODIADEMA EMERSONI Clark.

Plate V, figures 1a–e.

Pseudodiadema emersoni Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 45, 46, Pl. XII, figs. 2a–e.

Determinative characters.—Test circular, depressed. Ambulacra straight and prominent; poriferous zones narrow; pores uniserial. Interambulacra not quite twice the width of the ambulacra with two rows of large tubercles, eight or nine in each row. Peristome wide.

Dimensions.—Diameter 15 millimeters; height 7 millimeters.

Description.—The beautifully preserved molds of this interesting form were collected by Hyatt from the Jurassic beds of Taylorsville, Cal. The gutta-percha casts from which the drawings were made represent very perfectly all the details of structure. The test is nearly circular, the prominent ambulacra are rather more than one-half the width of the interambulacra, and support two rows of primary tubercles somewhat smaller than the interambulacral tubercles. There are nine or ten in each row. Between the tubercles are numerous granules that are arranged in an undulating line between the rows and along the margin. They nearly disappear between the tubercles of the same series. Toward the apical system the tubercles are greatly reduced in size. The pores are uniserial, there being three or four opposite each ambulacral plate.

The interambulacra bear two rows of primary tubercles, eight or nine in each, that are only slightly larger than those of the ambulacral areas. They increase from the peristome to the ambitus, after which they rapidly decrease in size. The areolas are nearly confluent above and below, broader than long, and rise into prominent bosses that are not deeply crenulated. The mamelon is distinctly perforated. The miliary space is covered with granules of different sizes. There are no secondary tubercles developed near the peristome. The lower surface is flat, the peristome large and deeply notched; the ambulacral lobes larger than the interambulacral. The apical system is not preserved. This species is named in honor of B. K. Emerson, of Amherst College, from whom the writer received his first instruction in geology and paleontology.

Related forms.—The species is unique, being the only Pseudodiadema in the Jurassic of America and being only very doubtfully identical with any European form. It resembles *P. baileyi* from England in many particulars but is less depressed, has more rounded sides, and more numerous granules in the miliary space.

Locality.—Taylorsville, Plumas County, Cal.

Geologic horizon.—Mormon sandstone, Middle Jurassic.

Collection.—U. S. National Museum (30186).

Family PEDINIDÆ.

Genus STOMECHINUS Desor.

STOMECHINUS HYATTI Clark.

Plate V, figures 2a–e.

Stomechinus hyatti Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Stomechinus hyatti Clark, 1893, U. S. Geol. Survey Bull. 97, p. 56, Pl. XXIII, figs. 1a–e.

Determinative characters.—Test high, circumference circular. Ambulacra with four rows of small primary tubercles; poriferous zones wide, triserial. Interambulacra with eight or ten rows of tubercles that diminish in number toward apical system and peristome, with a depression along the line of the central suture.

Dimensions.—Diameter 25 millimeters; height 25 millimeters.

Description.—Only the cast of a portion of the exterior of a single specimen of this interesting Jurassic form is preserved. The test is high, and the circumference circular or slightly subpentagonal. The sides rise abruptly from the margin.

The ambulacra are about one-half the width of the interambulacra and preserve a nearly uniform width throughout. There are four rows of tubercles that increase gradually in size from above downward. A depression appears along the line of the central suture. The poriferous zones are wide; the pore pairs are placed in oblique ranks of three, and each rank is separated from that next to it by two small tubercles.

The interambulacra are about twice the width of the ambulacra and the plates of the former are but slightly higher than those of the latter. Each plate is covered at the widest part of the area with an irregular row of four or five tubercles that are of about the same size as those of the ambulacra. The tubercles are uncrenulated and imperforate. A wide depression extends along the medial line of each interambulacral area, according with the position of the central suture.

The regions of the apical disk and peristome are largely wanting, but a deep incision shown upon the margin of the latter indicates that it is distinctly lobed throughout.

Related forms.—The American species shows some points of identity with *Stomechinus nudus* Wright of England but is more elevated, has a less sharp marginal angle, and has a more regular arrangement of the tubercles.

Locality.—Taylorsville, Plumas County, Cal.

Geologic horizon.—Mormon sandstone, Middle Jurassic.

Collection.—U. S. National Museum (30185).

Subclass IRREGULARIA.

Order GNATHOSTOMATA.

Suborder HOLECTYPINA.

Family PYGASTERIDÆ.

Genus HOLECTYPUS Desor.

HOLECTYPUS PEALEI Clark, n. sp.

Plate V, figures 3a–b.

Determinative characters.—Test subcircular, subconical. Ambulacra rather narrow, nearly straight; poriferous zones distinct. Interambulacra prominent with large plates. Apical system imperfect.

Dimensions.—Diameter 15 to 25 millimeters; height 10 to 15 millimeters.

Description.—Several casts of a typical Holectypus from the Jurassic beds of Yellowstone River were collected by Peale in Montana many years ago but were never described. More recently a still more perfect specimen was obtained by W. H. Weed from the Yellowstone National Park, and this is made the type of the species. The specimens show the characteristic features of both the ambulacra and interambulacra, but the adoral and aboral regions are poorly preserved, as a result of which the characters of the apical system, peristome and periproct are

unknown. The ambulacra are very distinct, the poriferous zones showing clearly. The ambulacra are narrow, increasing in width gradually to the ambitus. The interambulacra stand out prominently, the sutures between the plates being clearly indicated.

Locality.—North of Berry Creek, Yellowstone National Park, Wyo.

Geologic horizon.—Jurassic.

Collection.—U. S. National Museum (31192).

Holectypus cragini Clark, n. sp.

Plate V, figure 4.

Holectypus ? sp. Cragin, 1905, U. S. Geol. Survey Bull. 266, p. 35.

Determinative characters.—Test subcircular, subconical. Ambulacra narrow, straight, with several rows of tubercles; poriferous zones straight and narrow. Interambulacra wide. Apical system imperfect.

Dimensions.—Diameter 28 millimeters; height 15 millimeters.

Description.—The fragmentary specimen referred to by Cragin is an unquestioned Holectypus and presents many of the diagnostic characters of that genus. It is not unlike *H. planatus* in general outline, but its much earlier geologic position renders it necessary to place it in an independent species. The test is much damaged, so that its essential specific characters can not be determined. The outlines of the ambulacra and interambulacra can be seen, but the individual plates are with difficulty distinguished. The ambitus is relatively sharp, indicating a flat undersurface. The tubercles in this species are evidently small and cover the greater portion of the plates. The apical system is small but the individual plates can not be distinguished.

Related forms.—This species is wholly unlike *H. peali* in form and is evidently a different species.

Locality.—Malone Mountain, Texas.

Geologic horizon.—Malone formation, Upper Jurassic.

Collection.—U. S. National Museum (31193).

Order ATELOSTOMATA.

Suborder ASTERNATA.

Family CASSIDULIDÆ.

Genus PYGURUS Agassiz.

Pygurus sp.

Pygurus sp. Cragin, 1905, U. S. Geol. Survey Bull. 266, p. 36.

Description.—Cragin describes the form as follows:

Among the specimens submitted by Dr. Stanton is a fragment of the test of a sea urchin of the genus Pygurus. It includes the main part of the aboral half of an ambulacrum. The genus is clearly determined by the form of the ambulacrum and the form and arrangement of the pores, as well as by the character of the tubercles and by the discoidal form of the test, the latter form being indicated by the flatness of the part preserved. The ambulacrum has the biconcave outline that characterizes the upper part of that of Pygurus. The pores of the outer row are very long and slitlike, widened slightly toward the outer end, and subhorizontal to more or less oblique; those of the inner row more ringent, compressed dotlike or hyphen-like, and oblique, their width being considerably less and their length considerably more than that of any of the circumtubercular courts on the neighboring part of the ambulacrum. The ambulacral plates are exceedingly narrow; the imperforate part of each, in the widest part of the ambulacrum, being about 10 times as long (transverse) as wide (parallel to the course of the ambulacrum) and ornamented with 1 to 3 small perforated tubercles, each of which is set in a round, depressed court. The distinction of these tubercles is irregular, but they are so few and so feebly developed on the inner ends of the plates as to give the ambulacrum the aspect of having a median plain zone, to which the seams between the plates give a transversely striated appearance.

Measurements.—Maximum width of ambulacrum 16, of which the two pore belts each occupy 3.5 and the imperforate tract 9 millimeters; length and width of each imperforate part of an ambulacral plate in broadest part of the ambulacrum, respectively, 4.5 and 0.43 millimeters; length of outer slitlike pores in broadest part of ambulacrum 2 millimeters, which is about one-fourth of the width of a semiambulacrum.

Occurrence.—West side of Malone Mountain, about 2 miles southwest of Malone station, in No. 25 of Dr. Stanton's Malone Mountain section; with *Gryphæa mexicana, Pleuromya inconstans, Pinna quadrifrons*, etc.

Geologic horizon.—Jurassic.

Collection.—U. S. National Museum.

CRETACEOUS ECHINODERMATA.

Class CRINOIDEA.

Subclass DICYCLICA.

Order INADUNATA.

Suborder DENDROCRINOIDEA.

Family PENTACRINIDÆ.

Genus PENTACRINUS Blumenbach.

PENTACRINUS TEHAMAENSIS Clark, n. sp.

Plate VI, figure 1.

Determinative characters.—Column composed of small and medium sized pentagonal joints, some with and some without sharp reentering angles. Crenulated ridges petaloid. Column perforated by a small canal.

Dimensions.—Column: Diameter of joint 3 to 6 millimeters; thickness of joint ½ to 1 millimeter.

Description.—Numerous isolated fragments of Pentacrinus columns have been found in the California Cretaceous. The larger joints are of medium size. Many very small joints are found with the larger ones and probably belong to the same species. The crenulations are distinct and form five well-marked petaloid areas on the upper and lower surfaces of the joints. The column is perforated by a small central canal.

Localities.—Shelton's ranch, 5 miles north of Paskenta, Tehama County (type), and Texas Springs, Cal.

Geologic horizon.—Knoxville formation, Lower Cretaceous, and beds doubtfully assigned to the lower part of the Chico formation, Upper Cretaceous.

Collection.—U. S. National Museum (31194).

PENTACRINUS BRYANI Gabb.

Plate VI, figures 2a–b.

Pentacrinus bryani Gabb, 1876, Acad. Nat. Sci. Philadelphia, Proc., vol. 28, p. 178, Pl. V, figs. 1, 1a, 1b.
Pentacrinus bryani Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Pentacrinus bryani Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 28, 29, Pl. III, figs. 3a–b.
Pentacrinus bryani Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 6.
Pentacrinus bryani Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 276–277, Pl. VI, figs. 8, 9.

Determinative characters.—Column composed of moderately large, rather thick, pentagonal joints, with sharp reentering angles. The crenulated ridges are broadly petaloid and each area is rounded at its outer extremity. Column perforated by canal of medium size.

Dimensions.—Column: Diameter of joint 6 millimeters; thickness of joint 1 millimeter.

Description.—Two small fragments of the stem of this form were described by Gabb in 1876. As the first representative of this family reported from the American Cretaceous it possesses considerable interest. The column is composed of moderately large, thick joints, that reach about 6 millimeters in diameter and about one-fifth of that in thickness. The broad, rounded ridges at the salient angles of the pentagonal outline form a nearly unbroken line, and the furrow at the reentering angles is alternately depressed and elevated in successive joints. The edge

of each joint is slightly rounded. The crenulated surfaces form five broad petaloid areas distinctly rounded at the outer extremities and unite near the inner edge of the reentering angles to form a double flat-topped ridge that reaches to the central canal, around which there is likewise a slight elevation. The crenulations are clearly visible on the outer surface of the column. The column is perforated by a central canal of medium size.

Related forms.—This species is quite unlike other species of American Pentacrinidæ and is distinguished from *Pentacrinus tehamaensis* Clark of the Pacific coast by its deeper reentering angles.

Locality.—Vincentown, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collections.—Academy of Natural Sciences of Philadelphia (1458); Johns Hopkins University.

Family UINTACRINIDÆ.

Genus UINTACRINUS Grinnell.

Uintacrinus socialis Grinnell.

Plate VI, figures 3a–h; Plate VII, figures 1a–c.

Uintacrinus socialis Grinnell, 1876, Am. Jour. Sci., 3d ser., vol. 12, pp. 81–83, Pl. IV, figs. 1–2b.
Uintacrinus socialis Meek, 1876, U. S. Geol. and Geog. Survey Terr. Bull., vol. 2, No. 4, pp. 375–378, figs. A–B.
Uintacrinus socialis Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 21–24, Pls. I, II.
Uintacrinus socialis Williston and Hill, 1894, Kansas Univ. Quart., vol. 3, No. 1, pp. 19–21 and diagram.
Uintacrinus socialis Bather, 1896, Zool. Soc. London Proc. for 1895, pp. 974–1004, Pls. LIV–LVI, 13 figs.
Uintacrinus socialis Logan, 1898, Kansas Univ. Geol. Survey, vol. 4, pp. 481–483, Pls. XXI, CXII.
Uintacrinus socialis Beecher, 1900, Am. Jour. Sci., 4th ser., vol. 9, pp. 267–268, Pls. III, IV.
Uintacrinus socialis Springer, 1900, Mus. Comp. Zool. Mem., vol. 25, No. 1, pp. 1–89, Pls. I–VIII.
Uintacrinus socialis Schuchert, 1904, Smithsonian Misc. Coll., vol. 45, p. 450, Pl. CIII.
Uintacrinus socialis Bassler, 1909, Smithsonian Misc. Coll., vol. 52, pp. 267, 269, Pls. XVII, XVIII.

Determinative characters.—Calyx globose; composed of very thin, usually rather flat, although sometimes decidedly convex plates, joined together by a very loose suture; faces at times marked by faint, irregular, vertical grooves. Column wanting. Base or apical system probably dicyclic, composed of centrale surrounded by circlet of basals (B) or circlet of infrabasals (IB) and basals (B) as the case may be. Encircling the base and alternating with the basals are five abutting radials (R) either heptagonal or hexagonal in form. Succeeding the radials are two primary brachials (IBr) the second (IBr2) axillary and generally pentagonal in form; separated by interbrachials (iBr) which may vary in number from 3 or 4 to 23. Branching from the axillary brachial are the secundibrachs (IIBr) or distichals, generally the first eight of which are fixed, entering into the composition of the dorsal cup. Between the secundibrachs are intersecundibrachs (iIIB) or the interdistichals, which with the lower pinnulars and the interpinnulars of all areas are fixed. The normal order of succession of pinnulars is IIBr2 outer IIBr4 inner IIBr5 outer IIBr7 inner IIBr8 outer, beyond which each brachial bears a pinnule on alternate sides except where there is a syzygy, when only the epizygal is pinnule-bearing. Ventral disk or tegmen composed of plates skin covered with small calcareous plates or spicules. Mouth excentric, the ambulacra diverging from point near margin of disk. Anus central, large and conical.

Dimensions.—Width of calyx 6.25 to 75 millimeters; medium-sized specimen 40 millimeters; length of arms 100 centimeters.

Description.—The writer of this paper gave in 1893 a more extended description of *Uintacrinus socialis* than his predecessors had done and was able for the first time to show the structure of the base, which was fairly well preserved on a single specimen. The small amount of material at his disposal rendered it impossible to detect some important structural features observed by later writers who had access to more abundant and better preserved specimens.

S. W. Williston and B. H. Hill described better specimens of *Uintacrinus socialis* found by E. E. Schlosson in Logan County, Kans. Williston pointed out that these were the first speci-

mens found in place and unweathered. He says that the long arms were so entangled as to make it very difficult to trace them to their extremity.

The collection by H. T. Martin of a large number of specimens of *Uintacrinus socialis* from Williston's locality in western Kansas furnished several museums, among them the British Museum and the Peabody Museum of Yale University, with new and valuable material. The material acquired by the British Museum was very thoroughly studied in 1895 by F. A. Bather, whose morphologic study of this species added much to what was previously known. A large slab acquired by Yale University was described by C. E. Beecher in 1900.

The complete description of *Uintacrinus socialis* and the true interpretation of its structure and relations were not made until 1901, when Springer obtained from western Kansas, through the intelligent collecting of H. T. Martin, a large and finely preserved lot of specimens, far more than had come into the possession of any of his predecessors. With his wide and accurate knowledge of the crinoids he has been able to add more than any of his predecessors to a knowledge of this interesting form and in addition to the discovery of dicyclic as well as monocyclic individuals, was also able to find a number of specimens with well-preserved tegmens so that for the first time a knowledge of the structure of the ventral surface of Uintacrinus was secured. The following description is largely based on Springer's elaborate discussion of this form.

The calyx is globose with 10 long simple arms bearing pinnules. The test must have been flexible. The calyx plates are thin, frequently convex and joined together by loose sutures, the faces of which are at times slightly grooved. The calyx is without column or stalk and belongs to the class of free forms.

The basis is composed of a centrale, surrounded by either a circlet of basals or a circlet of infrabasals, which are in turn surrounded by the basals. The centrale in the first form has its angles radially directed and in the second interradially directed. The form is, however, probably dicyclic. The infrabasal circlet is not complete in all specimens, some having only 4, 3, 2, or even 1 infrabasals.

The radials are five in number and surround the basals, with which they alternate. They are equal, six or seven-sided, the latter occurring where the edge toward the basis forms a reentrant angle. The radial plates are wider than high and come in contact with one another only in the lower portions of each side. They come in contact with the proximal interbrachials and support the first primibrachs.

Following the radials are the primibrachs, secundibrachs or distichals, and fixed pinnules, all of which enter into the formation of the calyx, to which are added interbrachials, interdistichals, and interpinnulars. It is not always easy to determine the exact limits of marginal attachment of the fixed brachial elements in the fossil state. There are two primibrachs, the first (IBr1) hexagonal in form abutting on the radial on its lower margin, and the second primibrach (IBr2) on its upper margin where latterly it comes into contact with interbrachials on either side. Both the first and second primibrachs are somewhat narrower than the radials. The second primibrach is axillary and generally pentagonal in form. It also abuts on interbrachials on either side and bears upon its upper margin the first of the secundibrachs.

The secundibrachs or distichals are commonly fixed in the first eight plates with the aid of the fixed pinnules, interbrachials, interdistichals, and interpinnulars. Those secundibrachs bearing fixed pinnules appear slightly axillary, which gives the appearance of a somewhat irregularly depressed series.

The normal order of succession of the fixed pinnules is first from the second secundibrach on the outer side, the next from the fourth secundibrach on the inner side, then from the fifth secundibrach on the outer side, then the seventh secundibrach on the inner side, and finally from the eighth secundibrach on the outer side. The intervening secundibrachs do not bear pinnules. Beyond this point each brachial bears generally on alternate sides a pinnule except where there is a syzygy when only the epizygal bears a pinnule. The fixed pinnules comprise four or five to ten of the proximal plates. The number of plates is greater in adults than in the young forms. United with the interbrachial and in many specimens with the interpinnular plates they form the interbrachial area of the calyx, and with the intersecundibrachs or interdistichals the inter-

distichal area of the calyx. Each interbrachial area contains in adults, usually six rarely eight, of these fixed pinnules. In the young four and even two have been found. The interdistichal area contains four fixed pinnules in adult forms and two, and at times apparently none, in the young. The amount of fixation therefore increases with age.

The interbrachial area consists of from three or four to twenty-three plates. The arrangement of the plates is very variable. When there are seven plates or less no one of the interbrachials is inclosed, but the plates are disposed in more or less irregular vertical rows. This arrangement holds in some specimens containing eight or even nine or ten plates. In other specimens one or more plates are inclosed. Variation in the interbrachial areas occurs in some individuals.

The intersecundibrachs or interdistichals may differ in the same way, the number varying from none to 8, although the most common number is from 2 to 5, the younger forms having less than the adults. The interpinnular plates are not present in all specimens, but one or two may be placed between the proximal portions of the fixed pinnules and the intervening secundibrachs. The interpinnulars generally appear in corresponding position on opposite sides of the same area.

The arms are the continuation of the secundibrachs or distichals and are therefore ten in number. They consist of brachials and pinnules, the latter disposed in the manner previously described. An arm branch 100 centimeters, or 40 inches, long has been described by Springer, who thinks it not improbable that a total spread of arms of 250 centimeters, or 8 feet 4 inches, may have occurred.

The ventral disk or tegmen has been described only by Springer, who prepared a number of specimens on which the disk was beautifully preserved. He states that it is composed of the plated skin, the membrane being of such a highly carbonaceous composition that it is jet black in the fossil. This membrane evidently inclosed the entire visceral mass and formed a lining where it is usually seen when the calyx is broken away. Upon the disk it is studded or paved with small calcareous plates or spicules which are not connected by suture but are embedded in the tegment touching each other. They are of irregular shape, variable in size, and without any definite plan of arrangement.

The central part of the disk is occupied by a large, conical anal tube, shaped like an inverted funnel, which is perhaps an extension of the ventral disk above described. It is also composed of a plated skin, the granules of the disks passing gradually into it and becoming more and more elongate, until toward the distal end where the opening was they become threadlike.

The mouth is excentric, and the ambulacra diverge at a point near the margin of the disk. Two of them follow around the margin in a large hood-shaped cone, closing the anal tube. These branch on either side so as to connect with the arms of the posterior rays. The next pair of ambulacra are shorter; they branch and supply two lateral rays. A single groove runs to one branch of the anterior ray and the other branch does not seem to have any groove leading to it. The ambulacral grooves are simply depressions in the peristome. There is no trace of any covering plates or anything like an ambulacral skeleton.

Localities.—The first specimen of this species was found by O. C. Marsh in the Uinta Mountains, Utah. Grinnell established the genus Uintacrinus on much better preserved material from Trigo County, Kans. Still better specimens were later found in Logan County, Kans., which has been the source of most of the fine material in the various museums of the world. It is from this locality that Springer secured a few years ago the superb specimens that are the basis of his elaborate monograph.

Geologic horizon.—Niobrara chalk, Upper Cretaceous.

Collections.—Museum of Comparative Zoology, Cambridge; U. S. National Museum (8044); University of Kansas; Yale University; British Museum; Johns Hopkins University.

Family MARSUPITIDÆ.

Genus MARSUPITES Miller.

Marsupites americanus Springer.

Plate VII, figures 2a, 2b, 3.

Marsupites americanus Springer, 1911, Mus. Comp. Zool. Mem., vol. 25, No. 3, pp. 158–161, Pl. VI, figs. 4a, 4b, 5.

Springer describes the species as follows:

Determinative characters.—Calyx globose, wider than high; widest about middle of basal, contracting toward the arm bases. Centrale larger than infrabasals. * * * Radial facets shallow, facing almost vertically; filling about half the distal face of radial, and having a straight muscular articulation. Primibrachs 2; succeeding brachials to the number of seven in the longest arm preserved wide and very short, with an alternating cuneiform arrangement and an indication of syzygies between Br3 and 4; ventral groove broad and shallow. A good-sized triangular interbrachial plate, having straight sides and apparently joined to the brachials by suture, fills the space between the arm bases. All plates very thin, and covered with moderately fine radiating striæ crossing the sutures and converging at the centers; a strong ridge runs upward from the center of the basals, two meeting at each radial facet. Further structures unknown.

Dimensions.—Centrale: Diameter of pentagon 18 millimeters; IBB 17 millimeters high by 17.5 wide; BB 18 millimeters high by 18 wide; RR 11 millimeters high by 14 wide; radial facets 6 millimeters wide. In a large fragment the centrale is 25 millimeters wide.

Description.—The general outline and surface ornament of this species are not different from what may be seen among specimens of *M. testudinarius* of the English chalk from Sussex and other places. These vary from coarse to fine striæ and with such a thin, pliant calyx the contour of the fossil is largely a matter of pressure in its deposition. Measurements of plates shows no substantial difference between the two, an average of five specimens of the English species being as follows: Centrale, 19.1 millimeters wide; IBB, 19.6 millimeters high by 19.5 wide; BB, 19.6 millimeters high by 20.1 wide; RR, 12.6 millimeters high by 15.7 wide; R, facets 8 millimeters wide. The only real difference observable in the parts preserved is that in our species the brachials are shorter and wider than in *M. testudinarius;* and if we had enough specimens with brachials attached to get an average, this might disappear. The calyx figured is smaller than the English species usually appears, but the other fragmentary specimen has plates fully as large as that. The species is rare and has only been found at the type locality.

Locality.—Plymouth Bluff, Miss.

Geologic horizon.—Tombigbee sand member of the Eutaw formation, Upper Cretaceous.

Collection.—Collection of Frederick Braun.

Order FLEXIBILIA.

Suborder PINNATA.

Family BOURGUETICRINIDÆ.

Genus RHIZOCRINUS M. Sars.

Rhizocrinus alabamensis (De Loriol).

Plate VII, figures 4a–c.

Bourgueticrinus alabamensis De Loriol, 1882, Cincinnati Soc. Nat. Hist. Jour., vol. 5, p. 118, Pl. V, figs. 1, 1a, 1b.
Rhizocrinus alabamensis Carpenter, 1884, Challenger Repts., vol. 11, pt. 2, p. 257.
Bourgueticrinus alabamensis Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Bourgueticrinus alabamensis Clark, 1893, U. S. Geol. Survey Bull. 97, p. 25, Pl. III, figs. 1a–c.

Description.—As it has been impossible for the writer to obtain possession of the type of this species the description of De Loriol, as translated by S. A. Miller, is given verbatim:

This species is as yet known only by the basal cone which supports the calyx, and which is composed of several enlarging segments of the column surmounted by the basal plates. The height of the inverted cone is 5 millimeters; the diameter of the basal plate is 3½ millimeters; and that of the inferior segment of the column is 3 millimeters in its major axis. Its form is faintly swollen in the middle; the surface is smooth. The sutures are very indistinct, and it is a difficult matter to determine what was the height of the basal plate. The superior face of the cone carries five slender and compatively elevated radiating ridges, which bound five deep depressions in which the basal pieces of the calyx were lodged; in the center an enlargement of the central canal constitutes the bottom of the calyx cavity. The articular face of the lower joint of the column forming the inferior end of the cone is elliptical, but the length of its major axis does not, however, much exceed that of its minor axis. It is slightly concave and encircled by a feeble rim along

the circumference line; the transverse articular ridge process is reduced to two elongated tubercles which proceed from the marginal rim. Central canal comparatively large.

Although this species is still very imperfectly known one can affirm that it is certainly distinct from *Bourgueticrinus ellipticus* Miller, by the much less swollen form of the basal cone, which is but slightly convex in outline, and by the facts that the lower segment of the cone is already elliptical and already possesses the rudiments of a transverse articular ridge. Furthermore, the radiating carinæ are very much more salient, and consequently the depressions which they separate very much deeper. Finally, by its central canal being relatively much larger.

This species is referred to the genus Rhizocrinus, following the views of Carpenter and also from the possible close relationship of the form to *Rhizocrinus cylindricus* Weller from New Jersey.

Locality.—Livingstone, Ala. (De Loriol).

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—Cincinnati Society of Natural History.

Rhizocrinus cylindricus Weller.

Plate VII, figures 5a–g.

Rhizocrinus cylindricus Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 275, 276, Pl. VI, fig. 1.

Determinative characters.—Weller says:

Calyx cylindrical, slender and greatly elongate, the sides almost straight, not enlarging from the basals up. The proximal column joint (or joints ?) higher than the basals and radials together, cylindrical above with straight sides, slightly contracted below. Basals much higher than the radials. Radial facets shallow, curved, rather wide, separate, low and not sloping upward, having no conspicuous muscle plate or ligament fossa. They inclose a relatively large and well-excavated central funnel or visceral cavity.

Dimensions.—Height of proximal column joint and calyx together 9.3 millimeters; diameter 3 millimeters; height of proximal column joint 6 millimeters. Isolated joints: width 2 to 4 millimeters; height 3 to 3.5 millimeters.

Description.—This species is established on a single complete calyx and proximal stem joint, although numerous isolated column joints may belong to the same species. Several of these column joints were collected a number of years ago by the author. Figures of some of the more characteristic ones were first given by Weller from drawings furnished by the author and are repeated here.

Related forms.—The specimen is clearly a member of the family Bourgueticrinidæ and superficially resembles in some respects *Bourgueticrinus ellipticus* and *B. æqualis* from the White Chalk of England, but it differs from these species in the much greater height of its basals. The character of the radial facets and the larger visceral cavity, however, seem to remove it from that genus. In the great height of its basals the species agrees with members of the genus Rhizocrinus, but that genus is described as having a thin, disklike proximal stem joint, whereas the New Jersey species apparently has an exceedingly high one in which no transverse divisions can be detected. There seems to be no reason, however, why some latitude may not be allowed in this character. The genus Rhizocrinus has not heretofore been recognized earlier than the Eocene, but there is no reason why it should not also occur in the later Cretaceous.

The species is possibly allied to *Rhizocrinus alabamensis* (De Loriol) but differs from that species in having a much more slender form.

Locality.—Vincentown, N. J.

Geologic horizon.—Vincentown sand of the Rancocas group, Upper Cretaceous.

Collection.—New Jersey Geological Survey; Johns Hopkins University.

Class STELLEROIDEA.

Subclass ASTEROIDEA.

Order PHANEROZOMA.

Family ASTROPECTINIDÆ.

Genus ASTROPECTEN Schulze.

ASTROPECTEN (?) MONTANUS Douglas.

Plate VII, figure 6.

Astropecten montanus Douglas, 1903, Carnegie Mus. Ann., vol. 2, pp. 5–8, text fig.

Determinative characters.—Douglas says: "Size small; arms narrow and gradually tapering, longer than the diameter of the body; five radial elliptical figures on body, all except one nearly in line with the long axis of the arms."

Dimensions.—From the central pit to end of perfect arm 12 millimeters. From central pit to margin of body between the arms 3.5 millimeters.

Description.—Douglas in his description of the form says that the most prominent markings are the pits which probably represent the marginal plates. It is possible, however, that these may be impressions of the ambulacra. Halfway from the base to the end of the arm each row of pits is nearly as wide as the middle portion of the arm. Only one arm is complete. This has 12 pits on each side and they are opposite.

Locality.—South fork of Sixteenmile Creek, 23 miles north of Bozeman, Mont.

Geologic horizon.—Colorado shale, Upper Cretaceous.

Collection.—Carnegie Museum, Pittsburgh (601).

Family PENTAGONASTERIDÆ.

Genus PENTAGONASTER Schulze.

PENTAGONASTER BROWNI Weller.

Plate VII, figure 7.

Pentagonaster browni Weller, 1905, Jour. Geology, vol. 13, pp. 257, 258, fig. 1.

Determinative characters.—Weller says: "Stellato-pentagonal in outline. Disk large, apparently flat. Interradial area broadly rounded and rays elongate for the genus, rounded at the extremities. Marginal plates large, about sixteen occupying each interradial arc from tip to tip of adjacent rays, the character of their ornamentation not preserved."

Dimensions.—Major radius 24 millimeters; minor radius 11. 4 millimeters.

Description.—The specimen is apparently exposed from its dorsal side, but apart from the large marginal plates all the plates of this surface have been destroyed. The impressions of the ambulacral furrows of the ventral surface are exposed by the weathering away of the dorsal surface, and appear as rounded slightly elevated ridges extending from the arm pits to the center of the disk, but the characters of the ambulacra are not sufficiently well preserved to be accurately determined.

The presence of highly developed marginal plates on the specimen mark it at once as a member of the order Phanerozonia, and it may be placed, without serious question, in the family Pentagonasteridæ. The reference of the specimen to its proper genus is less satisfactory, but it seems to agree more closely with Pentagonaster than with any other, although the interradial arcs are somewhat deeper than is usual in that genus. In the recent species *P. arculatus* Sladen,[1] however, these arcs are nearly as deep as in the fossil specimen, the proportion between the minor and major radii being 1 to 1.93, against 1 to 2.08 in the fossil specimen.

[1] Challenger Reports, Zoology, vol. 30, p. 277, Pl. LII, figs. 1, 2.

The specimen also more or less closely resembles, in the characters preserved, some of the recent species of Gnathaster, a genus also belonging to the family Pentagonasteridæ, in which the interradial arcs are in many specimens much deeper than in Pentagonaster, the proportion of the minor to the major radii in *G. elongatus* Sladen [1] being 1 to 3.5. Gnathaster, however, is customarily characterized by the presence of an odd interradial marginal plate, a character not clearly shown in the fossil specimen. In one of the interradia such a plate seems to be present, but in the others not. For the present, therefore, the specimen may be referred to the genus Pentagonaster (Weller).

Locality.—SE. ¼ sec. 16, T. 32 N., R. 99 W., near Lander, Wyo.

Geologic horizon.—Montana group, Upper Cretaceous.

Collection.—Walker Museum, Chicago.

Family ATHENEIDÆ.

Genus GONIASTER Agassiz (em. Per.).

Goniaster mammillata Gabb.

Plate VIII, figures 1a–h.

Goniaster mammillata Gabb, 1876, Acad. Nat. Sci. Philadelphia Proc., vol. 28, pp. 178, 179, figs. 2, 2a, 2b.
Goniaster mammillata Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Goniaster mammillata Clark, 1893, U. S. Geol. Survey Bull. 97, p. 32, Pl. V, figs. 1a–h.
Goniaster mammillata Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 6.
Goniaster mammillata Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 277–278, Pl. VI, figs. 10–17.

Determinative characters.—Body pentagonal, provided with a dorsal and a central row of marginal plates that are narrower than high, and distinctly tumid on their outer surfaces. Only detached marginal plates preserved.

Dimensions.—Plates: Height 3 to 8 millimeters; thickness 2.5 millimeters.

Description.—Gabb mentions the discovery of about thirty detached marginal plates of this species. Many more have been found by the author. They differ widely in shape from their position on the margin, but among those examined the majority are higher than wide and are swollen on the outer surfaces. Certain of the plates show marked protuberances upon the general level of the plate. The surface of the plates is punctate, the small depressions being arranged in rows that cross one another at right angles.

Related forms.—No American forms are similar enough to this species to be confounded with it. Lack of knowledge of all characters except those of a few marginal plates renders wide comparisons impossible.

Locality.—Vincentown, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collections.—Academy of Natural Sciences of Philadelphia (1457); Johns Hopkins University.

Family PENTACEROTIDÆ.

Genus PENTACEROS Linck.

Pentaceros asperulus Clark.

Plate VIII, figures 2a–b.

Pentaceros asperulus Clark, 1907; in Weller, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 278–279, Pl. VI, figs. 18, 19.

Determinative characters.—Body pentagonal with long, narrow arms; covered with irregularly shaped plates that touch intermittently at their margins, the surface uneven and bearing spines. Detached body plates alone found.

[1] Idem, p. 288, Pl. XLVIII, figs. 1, 2.

Dimensions.—Type specimen: Length 6.5 millimeters; width 4 to 5 millimeters; thickness 3.5 millimeters.

Description.—Two or three well-preserved specimens of the small surface plates of a Pentaceros have been found by the writer. They are so highly characteristic that their generic relations are clearly apparent. As no other Cretaceous representatives of this genus have been found in American deposits they have been given a specific name.

The plates are irregular in outline, the intermittent articulating surfaces on the perimeter producing a roughly polygonal outline. The surface of the plates is uneven, the irregularly flattened areas providing attachment for spines. The central portion of the plates is higher than the truncated margins.

Related forms.—No other American Cretaceous representatives of this genus are known, and the plates can not readily be associated with any known European species.

Locality.—Vincentown, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collection.—Johns Hopkins University (T 3014).

Subclass OPHIUROIDEA.

Order ZYGOPHIURÆ.

Family OPHIOLEPIDIDÆ.

Genus OPHIOGLYPHA Lyman.

OPHIOGLYPHA TEXANA Clark.

Plate VIII, figures 3a–c.

Ophioglypha texana Clark, 1893, U. S. Geol. Survey Bull. 97, p. 30, Pl. IV, figs. 1a–c.

Determinative characters.—Disk round; composition indistinct. Arms long, with wedge-shaped under-arm plates about as wide as long; upper arm plates about twice as wide as long.

Dimensions.—Diameter of disk 4 millimeters; length of arm 50 millimeters; width of arm at disk 2 millimeters.

Description.—The determination of this species is dependent on three fairly well preserved forms that are grouped upon a single slab of limestone, all with the lower side exposed. The surface upon which they rest is considerably weathered, and many of the details of structure have consequently suffered. The general form of the disk is preserved, although its composition can not be made out. Many of the arm plates have disappeared, leaving only the skeletal pieces. Where preserved, the under-arm plates are wedge-shaped and about as wide as long. The upper-arm plates, which are shown only as impressions upon the limestone, are nearly twice as wide as long and have their lateral edges rounded.

Locality.—Six miles north of Fort Worth, Tex., on the banks of Fossil Creek. Associated with *Ostrea quadriplicata* Shumard, *Stearnsia robbinsi* White, and *Leiocidaris hemigranosus* (Shumard).

Geologic horizon.—Denison formation of the Washita group, Comanche series, Cretaceous.

Collection.—U. S. National Museum (21884).

OPHIOGLYPHA BRIDGERENSIS (Meek).

Plate VIII, figures 4a–b.

Ophioderma? bridgerensis Meek, 1873, U. S. Geol. and Geog. Survey Terr. Rept. for 1872, pt. 2, p. 475.
Ophioderma? bridgerensis White, 1883, U. S. Geol. and Geog. Survey Terr. Rept. for 1878, pt. 1, pp. 8, 9, Pl. XII, fig. 12a.
Ophioglypha bridgerensis Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Ophioglypha bridgerensis Clark, 1893, U. S. Geol. Survey Bull. 97, p. 29, Pl. IV, figs. 2a–b.

Determinative characters.—Disk composed of numerous small imbricating plates. Upper-arm plates wider than long, the outer angles sharp and extending between the side-arm plates, which are slightly smaller. Under-arm plates long and nearly rectangular in shape.

Dimensions.—Diameter of disk 5 millimeters; length of arm 20 millimeters; width of arm near disk 1½ millimeters.

Description.—The single specimen of this species thus far found is described in a footnote to a list of specimens reported by F. B. Meek in 1872, and redescribed and figured by C. A. White in 1878. This specimen, which has been carefully examined by the writer, presents the upper surface of the disk and fragments of the five arms. Upon four of the fragments the upper and side arm plates are shown, and upon the fifth a small portion of the under surface with the under arm plates and ambulacral openings is preserved.

The disk is described by Meek as "depressed, nearly circular, showing on the dorsal side ten ovate-subtrigonal radial plates, that are joined together over the inner ends of the arms, so as to form five pairs." A close examination of the specimen shows that the disk is made up of numerous small imbricating plates, and that the supposed division into ten mentioned by Meek may be explained by the fractured condition of the poorly preserved specimen.

The arms are small and are, as stated by Meek, perhaps three-fourths of an inch in length, although none of them are preserved entire. The upper-arm plates are wider than long and hexagonal in form. The outer angles are sharp and are embraced between the upper portions of the side plates. The latter are slightly swollen but are not shown in their entire length. The lower arms are poorly preserved but so far as exhibited are long and narrow, nearly rectangular in shape, and slightly swollen in their central portions.

Related forms.—Some doubt exists as to the generic position of this species. So many of the distinctive characters are wanting that a definite determination is quite impossible, but from the apparent structure of the disk, formed of numerous imbricating plates, its reference to Ophioglypha seems probable. The only other form, *O. texana*, has, so far as can be discerned, a somewhat smaller and differently constructed disk, and both the upper and under arm plates are of different shape.

Locality.—The "last foot of Bridger Peak, 4 miles north of Fort Ellis, Mont." (Meek).

Geologic horizon.—Associated with species of the genera Gryphæa, Avicula, Inoceramus, Crassatella, Pholadomya, Turritella, and Gyrodes, that denote the Cretaceous age of the strata (Meek). Upper Cretaceous, most probably Colorado shale.

Collection.—U. S. National Museum (7820).

Class ECHINOIDEA.

Subclass REGULARIA ENDOBRANCHIATA.

Order CIDAROIDEA.

Family CIDARIDÆ.

Genus CIDARIS Leske.

Cidaris tehamaensis Clark, n. sp.

Plate IX, figure 1.

Determinative characters.—Test unknown. Spines large and club-shabed, with rows of granules extending from neck to point of spine.

Dimensions.—Spine: Length 30 millimeters; width in thickest part 12 millimeters.

Description.—This species is represented by a well-preserved spine that is large and club-shaped. The granules are large and disposed in rows extending from the neck to the point of the spine.

Locality.—Shelton's ranch, Tehama County, Cal.

Geologic horizon.—Knoxville formation, Lower Cretaceous.

Collection.—U. S. National Museum (31195).

Cidaris texanus Clark.

Plate IX, figures 2a–f.

Cidaris texanus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 75.
Cidaris texanus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 61.
Cidaris texanus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 36, 37, Pl. VII, figs. 1a–e.

Determinative characters.—Test large, inflated. Ambulacra narrow, sinuous, with four rows of granules between the poriferous avenues, which at the ambitus are increased to six and toward the apical system and peristome are reduced to two rows. Pores oval, separated by transverse elevations, which partially envelop the openings. Interambulacra wide, with large circular tubercles. Areola circular, depressed; boss smooth; mamelon small, perforated. Miliary space wide, covered with numerous small granules.

Dimensions.—Diameter 80 millimeters (?); height 40 millimeters (?).

Description.—A large portion of the test of this beautiful species is excellently preserved. All of the characteristic features, except those relating to the apical system and peristome, are clearly shown. The test, however, is somewhat compressed, so that the original form can not be made out with certainty. The ambulacral areas are narrow and slightly flexuous. Between the poriferous avenues, which are narrow and depressed, are four rows of granules of nearly equal size, which directly at the ambitus are increased to six, and toward both apical system and peristome are reduced to two. Irregularly scattered among the rows of granules are others smaller in size. The pores are oval and separated by transverse elevations that partly encircle the openings, leaving a depression between each pair.

The interambulacral plates are wide and bear large circular tubercles. The areola of each tubercle is radially ridged, deeply depressed, and surrounded by a row of mammillated granules. The boss is slightly elevated above the level of the plate and presents a smooth and sharp ridge around the small perforated mamelon. The miliary space is wide and thickly set, with small elevated granules of equal size. The apical system and peristome are lacking.

Related forms.—At first sight the species shows strong points of similarity to *C. sceptrifera* Mantell from the White Chalk of England, although the arrangement of granules in its ambulacra is different. The areola of *C. sceptrifera* is described as smooth, and that of *C. texanus* as clearly ridged radially. The only related form reported from Texas is *Leiocidaris hemigranosus*, formerly referred to Cidaris, but which, as will be shown, does not belong to that genus. *Cidaris branneri*, from Brazil, described by White, is allied to *C. texanus*, but differs from it in the character of the areola and the arrangement of granules in both the ambulacral and interambulacral areas.

Locality.—Bexar County, Tex.

Geologic horizon.—Washita group of the Comanche series, Cretaceous.

Collection.—U. S. National Museum (8381).

Cidaris walcotti Clark.

Plate IX, figures 3a–d.

Cidaris walcotti Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 75.
Cidaris walcotti Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Cidaris walcotti Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 37, 38, Pl. VI, figs. 4a–d.
Cidaris walcotti Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 6.
Cidaris walcotti Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 281–282, Pl. VII, figs. 10–13.

Determinative characters.—Test small, inflated. Ambulacral areas narrow, sinuous, with four rows of granules between the depressed poriferous avenues. Interambulacral areas broad; each tubercle with depressed circular areola, smooth boss and small imperforate mamelon. Miliary space wide, thickly covered with small granules.

Dimensions.—Type specimen: Height about 25 millimeters; width about 37.5 millimeters.

Description.—The fragments of this form examined are sufficiently distinctive to separate it from other species. A nearly complete interambulacrum with the adjoining ambulacra shows that the test of the species is small and in a marked degree inflated.

The ambulacra are narrow, slightly sinuous, and provided with four nearly equal rows of granules between the poriferous avenues. On some additional granules are irregularly interspersed. The poriferous avenues themselves are narrow, deeply depressed, and slightly sinuous. The pores are round, with funnel-shaped openings, produced by the intersecting ridges. These ridges, which separate the individual pores and the pore pairs, give a lattice-like appearance to the poriferous zones.

The interambulacral plates are moderately large. On account of the indistinctly marked sutures the small tubercles and numerous granules cause a very even surface over the entire interambulacrum. The tubercles are circular and stand nearer the outer margin of the plates than the inner. The areolas are deeply depressed, the central portion but slightly exceeding the margin in height. The boss is smooth and stands but little above the level of the plate. The mamelon is imperforate. The wide miliary space is covered with a large number of irregularly arranged granules of equal size. The broken specimens afford no information as to the character of the apical system or peristome.

Related forms.—The species is very readily separated from *C. splendens*, the only other representative of this genus thus far reported from the Atlantic coast Cretaceous, by its possession of imperforate mamelons and wide miliary spaces, over which the granules are regularly scattered. The even surface of the test is likewise a distinguishing feature.

Localities.—Timber Creek (type) and Vincentown, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collection.—Academy of Natural Sciences of Philadelphia (1451); Johns Hopkins University.

Cidaris splendens Morton.

Plate IX, figures 4a–b, 5a–f, 6.

Cidaris (?) sp. Morton, 1829, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, p. 123.
Echinus sp. Morton, 1830, Am. Jour. Sci., 1st ser., vol. 17, p. 287; vol. 18, Pl. III, figs. 12, 13.
Cidarites splendeus [1] Morton, 1841, Acad. Nat. Sci. Philadelphia Proc., vol. 1, p. 132.
Cidarites armiger Morton, 1842, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 8, p. 215, Pl. II, fig. 1.
Cidaris armiger Gabb, 1859, Cat. Invert. Fossils Cretaceous formation, p. 18.
Cidaris splendens Gabb, 1859, Cat. Invert. Fossils Cretaceous formation, p. 18.
Cidaris armigera Agassiz, 1874, Revision of the Echini, p. 751.
Cidaris armiger Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 75.
Cidaris splendens Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Cidaris splendens Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 33–35, Pl. VI, figs. 3a–g.
Cidaris splendens Johnson, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 6.
Cidaris splendens Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 279–281.

Determinative characters.—Test of moderate size, spheroidal. Ambulacral areas narrow, flexuous, with four rows of granules between the pore pairs, the outer rows larger than the inner; imperfectly defined granules also appear between the pores of each pair. Interambulacral areas very wide, with seven or eight plates in each column, each plate bearing a tubercle of large size characterized by a wide circular areola, smooth boss, and small perforated mamelon. Miliary area small and covered with numerous thickly set granules of small size. Sutures sharply defined, depressed. Spines elongated, cylindrical, with longitudinal rows of sharp denticulated processes.

Dimensions.—Height 21.9 to 23 millimeters; width 34.4 to 40 millimeters.

Description.—The first mention of this form is made by Morton in 1829, when he doubtfully referred a few fragments to Cidaris without an attempt at specific determination. Several of the more important characters were then given, but as the material examined included only detached plates and a few spines the description necessarily lacked much of completeness. In 1841 he proposed the name *Cidarites splendens* and then more accurately defined the species. In 1842

[1] Morton doubtless intended to use the term *splendens* instead of *splendeus*, which is probably a typographic error. In the publication of 1842, where *armiger* is substituted, the form *splendens* is used.

he redescribed and now for the first time figured the same form as *Cidarites armiger*, a name which he stated he desired substituted for *C. splendens*. Gabb in 1859 employed both names, mistaking them for independent species, but refers to *C. splendens* as *C. splendeus*. The specimens examined by the writer were chiefly detached plates, although one nearly complete test and two entire or nearly entire interambulacral areas, with parts or all of the adjoining ambulacra, were also among this material. In these specimens the oral side is slightly more depressed than the aboral, although not to the extent exhibited in Morton's figure. The ambulacral areas, which are narrow and flexuous, have, between the poriferous avenues, four granules. In the center of each column of plates these granules are approximately of equal size, the outer rows slightly larger, but toward the disk or toward the peristome the inner rows abruptly diminish in size and finally disappear. The pores are oval in shape with funnel-like openings exteriorly. Each row of pores is separated from that which accompanies it in the same avenue by a row of imperfectly defined granules that form an undulating ridge.

The interambulacral areas are very wide and bear large tubercles, each of which covers the greater portion of its plate. Upon the larger plates, in the center of each column, the areolas are circular, but become somewhat oval toward both disk and peristome. The outer edge of each areola is surrounded by a circle of large granules that give it a crenulated appearance. The areola rises from its depressed margin, gradually at first, then rapidly, to the boss, which reaches a marked elevation above the general level of the plate. The boss is of moderate width and smooth. From its center rises the mamelon, which is small, perforated, and slightly flattened upon the upper surface. The miliary space is covered by small granules, which are most numerously developed along the median line of the interambulacra.

None of the specimens affords the apical system. Strong auriculæ show the presence of powerful jaws.

The spines are slender, elongated, cylindrical, with longitudinal, serrated ribs that gradually become obsolete toward the base. The collar is short and finely striated longitudinally. The acetabulum is bordered by a smooth margin and is perforated in the center.

Related forms.—In many particulars *Cidaris splendens* (Morton) resembles *C. serrata* Desor of the European Cretaceous, but differs from it in several others notably in having only four rows of granules between the poriferous avenues.

Localities.—Timber Creek (type) and Vincentown (figured specimens), N. J.

Geologic horizon.—Vincentown sand of the Rancocas group, Upper Cretaceous.

Collections.—Philadelphia Academy of Natural Sciences; Johns Hopkins University (T3002).

Cidaris dixiensis Cragin.

Plate IX, figures 7a–b.

Cidaris dixiensis Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 146. Pl. XLVI, figs. 15, 16.

Determinative characters.—Cragin says:

> Test rather small, thin; tubercles perforate, not crenulate, rather small and feebly elevated; areolæ feebly depressed; interambulacral plates ornamented with crowded rounded granules which increase in size (in the smaller plates, gradually) toward the areola, the largest granules forming an alternating double row around it.

Dimensions.—Height of interambulacral plates 6 to 7 millimeters; width 7 to 8 millimeters.

Description.—The isolated interambulacral plates, which are the only portions of the test known, indicate that the form was not in all probability a large one. The tubercles are but slightly elevated, and the areolæ are feebly depressed. The mamelon is small and perforated. The boss is smooth. The miliary space is relatively narrow, covered with granules larger toward the areola, where they form an alternating double row around it.

Related forms.—The characters given separate this species from all of the American species with which the writer is acquainted. In the facies of the interambulacral portion of the test, it bears considerable resemblance to *C. serrifer* Forbes, from which it differs in the form of the plates.

Locality.—Nine miles northeast of Dallas, Tex.

Geologic horizon.—Taylor marl, Upper Cretaceous.

Collection.—Geological Survey of Texas.

? Cidaris nahalakensis De Loriol.

Cidaris nahalakensis De Loriol, 1887, Recueil zool. Suisse, vol. 4, pp. 388, 389, Pl. XVII, figs. 3–4.
?*Cidaris nahalakensis* Clark, 1893, U. S. Geol. Survey Bull. 97, p. 93.

The species is based by P. de Loriol on fragments of spines obtained from the Selma chalk ("Rotten limestone") of the Upper Cretaceous of Wahalak, Kemper County, Miss. Similar spines have been recognized by the writer from other localities, but whether they represent an independent species or one hitherto described is not clear.

Genus LEIOCIDARIS Desor.

Leiocidaris hemigranosus (Shumard).

Plate X, figures 1a–g; Plate XI, figures 1a–b.

Cidaris hemigranosus Shumard, 1860, St. Louis Acad. Sci. Trans., vol. 1, p. 609.
Cidaris hemigranosus Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 2.
Cidaris hemigranosus White, 1883, U. S. Geol. and Geog. Survey Terr. Twelfth Ann. Rept., for 1878, p. 38, Pl. XVIII, figs. 2a–b.
Leiocidaris hemigranosus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 75.
Leiocidaris hemigranosus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 38, 39, Pl. VII, figs. 2a–d; Pl. VIII, figs. 1a–b; Pl. IX, figs. 1a–c.
Leiocidaris hemigranosa Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 160, Pl. XLVI, fig. 4.
Leiocidaris hemigranosus Hill, 1901, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pp. 252, 266, 272.

Determinative characters.—Test very large, subspherical. Ambulacra narrow, sinuous, with six rows of granules in the middle. Poriferous avenues, wide, deeply depressed. Pores of each pair united by clearly defined furrow. Interambulacra broad. Tubercles very large; areola circular or slightly polygonal, depressed; boss smooth, mamelon large, perforated. Miliary space covered with large scattered oval granules. Sutures clearly marked, depressed.

Dimensions.—Diameter 90 millimeters; height 67 millimeters.

Description.—The form, which was quite fully described by Shumard in 1860, but not figured, was incorrectly referred to the genus Cidaris, from which it is separated by the presence of furrows uniting the pores of each pair. In this respect it is a typical representative of the genus Leiocidaris of Desor. A very good illustration was given by White in 1883 (report for 1878), although necessarily, from the size of the figure, the furrows connecting the pores could not be very distinctly shown. This species is the largest echinoid known from the Texas Cretaceous, and with possibly a single exception the largest from the American Mesozoic. In one unusually fine specimen the test is subspherical, although considerably broader and more flattened on the oral than aboral side.

The ambulacra are narrow and sinuous, with six rows of granules between the poriferous avenues. The regular arrangement of the granules is not persistent, the number being increased irregularly near the middle of the column and somewhat reduced toward the apical system and peristome. The poriferous avenues are wide and deeply depressed, the pores of each pair being united by a shallow furrow.

The interambulacra are wide and the plates of massive size. The tubercles occupy the center of the plates and are large and prominent. The areolas are deeply depressed, subcircular or slightly polygonal, and occupy more than half of the greatest diameter of the plates. On all the specimens examined the areolas show perfectly smooth surfaces, although Shumard mentions the occurrence of radiating ridges. Toward the center each areola rises to form the boss, which is provided marginally with a sharp smooth ridge. The mamelon is large, subspherical, with a deep perforation upon its summit. The miliary space is wide and covered with large, irregularly shaped and flattened granules, some round and some oval in form. Interspersed among these are much smaller granules, which increase in number along the margin of the plates. The apical system and peristome are wanting.

Related forms.—The species is readily separated from any hitherto described from American or European strata. Its characters are well defined and distinctive.

Localities.—Upper part of the bluff of Red River, Lamar County, and 10 miles above the mouth of Kiamesha Creek (type); 3 miles west of Denison (figured specimen); railroad cut west of Austin; and "Gap," Travis County, Tex.

Geologic horizon.—Denison formation of Washita group, Comanche series, Cretaceous.

Collection.—U. S. National Museum (21768).

Subclass REGULARIA ECTOBRANCHIATA.

Order DIADEMOIDEA.

Suborder CALYCINA.

Family SALENIIDÆ.

Genus SALENIA Gray.

SALENIA TEXANA Credner.

Plate XII, figures 1a–i; Plate XIV, figures 1a–c.

Cidaris diatretum Giebel, 1853, Naturwiss. Ver. in Halle Jahresb. for 1852, p. 374, Pl. VII, figure 2.
Salenia texana Credner, 1875, Zeitschr. für gesam. Naturwiss., vol. 46, pp. 105–116, Pl. V, figs. 1–6.
Salenia texana Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 75.
Salenia texana Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Salenia texana Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 40, 41, Pl. X, figs. 1a–h.
Salenia texana Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., pp. 163, 164.

Determinative characters.—Test subglobose; upper surface convex; sides inflated; under surface flat. Ambulacra narrow, flexuous, with two rows of mammillated granules in each area; poriferous zones flexed; pores uniserial. Interambulacra wide, with two rows of alternating plates, six in each row. Apical system large, convex, subcircular; periproct prominent. Peristome moderately large.

Dimensions.—Diameter 10 to 25 millimeters; height 7 to 20 millimeters.

Description.—Credner presents the first complete diagnosis of a North American Mesozoic echinoid in the detailed descriptions accorded the present species. Its reference by Giebel in 1852 to *Cidaris diatretum* (=*Pseudodiadema diatretum*) was erroneous.

The test is subspherical when complete, but in many of the specimens examined is somewhat flattened, both actinally and abactinally. The lower surface is slightly concave in the vicinity of the peristome. The sides are inflated, presenting a rounded surface which is fuller above than below.

The ambulacra are narrow, increasing gradually in width from the apical system to the peristome. Two rows of mammillated granules, twenty-four to twenty-six in each, occupy the middle of each area. Very minute granules extend in a line between the rows and in the vicinity of the peristome surround the larger granules themselves. The poriferous zones are narrow and flexuous, and the pores are regularly arranged in a uniserial series; near the peristome they are slightly more crowded. The most pronounced flexure is opposite the second interambulacral plate from the apical system. Toward the peristome the zones become nearly straight.

The interambulacra are broad and formed of two alternating rows of broad plates, six in each row. The tubercles increase rapidly in size from the peristome, where they are scarcely larger than the mammillated granules of the ambulacra. The areolas are large and surrounded by mammillated granules of various sizes that are crowded together along the inner edge of the plates. Between the larger granules are numerous minute granules. The areola rises to a prominent boss that is deeply crenulated and bears an imperforate mamelon.

The apical system is very large, convex, subcircular, with radiating ridges that extend from the ovarial openings of each plate and unite with similar ridges of adjacent plates. Small punctures are found at the angles of the plates and intermediate between them. The subanal plate

is situated before the periproct and occupies the center of the disk. The periproct is subelliptical, rounded anteriorly, angular posteriorly, and slightly elevated at the border.

The adoral surface is flat and the peristome large, covering nearly one-half the diameter of the test. The peristome is circular, with ten incisions upon the edge that divide it into nearly equal sized lobes.

Related forms.—Credner in discussing the affinities of this form considers it to be closely related to *Salenia petalifera* Defrance and *S. desori* Wright. It is somewhat more elevated than *S. petalifera*, the radial ridges on its apical system are more pronounced, and its ocular plates enter more compactly into the composition of its disk. From *S. desori*, on the other hand, it differs more widely, both in the character of the test plates and the decorations of the apical system. With *S. scutigera* Gray it shows some points in common.

Localities.—Cileola, Comanche spring (figured specimen A); Bosque County (figured specimen B); 2½ miles north of Denison; 5 miles west of Kent; Bexar County; Round Rock; Williamson County, Tex.

Geologic horizon.—Fredericksburg and Washita groups of the Comanche series, Cretaceous.

Collections.—U. S. National Museum (8329, A); Boston Society of Natural History; Johns Hopkins University (T3003, B).

Salenia tumidula Clark.

Plate XIII, figures 1a–j.

Salenia tumidula Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 75.
Salenia tumidula Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Salenia tumidula Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 41, 42, Pl. XI, figs. 1a–j.
Salenia tumidula Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 6.
Salenia tumidula Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 282, 283, Pl. VIII, figs. 1–10.

Determinative characters.—Test small, subglobose; outline of upper surface regularly convex. Ambulacra narrow, nearly straight, with two rows of mammillated granules between the pore pairs; poriferous zones slightly flexed; pores uniserial. Interambulacra wide, composed of two alternating rows of five or six plates. Apical system large, regularly convex, subcircular; periproct slightly elevated. Peristome small.

Dimensions.—Diameter 2 to 13 millimeters; height 1 to 10 millimeters.

Description.—The perfectly preserved specimens of this beautiful species permit determination of all the details of structure.

The general form of the test is subglobose. The sides are inflated and regularly curved, rising into a convex upper surface, from which the periproct projects but slightly. The lower surface is almost flat and toward the peristome is slightly depressed.

The ambulacra are rather broad, increasing in width from the apical system to the peristome. Extending along the center of each area are two rows of mammillated granules, 15 or 16 in each row, between which are other minute granules. The poriferous zones are narrow and nearly straight; the pores round, regularly arranged in a uniserial series, and largest in the middle of the column.

The interambulacra consist of two rows of alternating plates, five or six in each row. The larger tubercles diminish rapidly in size toward the mouth edges, and are very indistinct on the plates bordering the same. Each areola is large and circular, the boss crenulated, and the mamelon flattened and imperforate. The miliary space is bordered with oval granules of irregular size and arrangement, although most numerous between the rows of tubercles. The sutures of the plates are very indistinctly marked.

The apical system is prominent, subcircular, with a regularly curved convex surface, from which the anal aperture projects but slightly. The granular decorations of the surface often coalesce and appear as broken ridges extending radially from the five openings in the genital plates. The periproct is oval, slightly pointed below, and projects but slightly above the level of the apical system. It is bordered by a flangelike edge that is formed of the anal and two genital plates.

The peristome is small, occupying scarcely two-fifths of the diameter of the test. Ten incisions divide the edge into lobes, the ambulacral lobes projecting the farther.

Related forms.—The identity of this species is readily established by the straight poriferous zones and peculiar decorations of the apical system. The number of mammillated granules in the ambulacral areas is less than in *S. texana*, and the oval granules of the interambulacral areas are readily distinguishable from the round forms of *S. bellula*. The periproct also projects far less than in *S. texana*, although in this respect it is not unlike *S. bellula*.

Locality.—Timber Creek, near Vincentown, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collections.—Academy of Natural Sciences of Philadelphia (1448); Johns Hopkins University.

Salenia bellula Clark.

Plate XIII, figures 2a–g.

Salenia bellula Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 75.
Salenia bellula Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Salenia bellula Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 43, 44, Pl. XI, figs. 2a–g.
Salenia bellula Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 6.
Salenia bellula Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 283–284, Pl. VIII, figs. 11–17.

Determinative characters.—Test small, compressed, circular; upper surface convex; sides inflated; under surface flat. Ambulacra rather broad, nearly straight, with two rows of granules in each row; poriferous zones broad, very slightly flexed; pores round, uniserial. Interambulacra wide. Apical system convex and nearly circular. Peristome small.

Dimensions.—Diameter 6 to 8 millimeters; height 10 to 13 millimeters.

Description.—This Salenia is a very rare form, only a few specimens having come under the notice of the writer. Certain peculiarities of outline and structure prevent its being confounded with other species heretofore described.

In general outline the test is somewhat flattened; the upper surface is regularly convex; the sides are inflated; the lower surface is flat or slightly concave at the peristome.

The ambulacra are prominent and change but slightly in width from the apical system to the peristome. Two rows of mammillated granules, 15 in each, occupy the center of each area.

The interambulacra are wide and consist of two rows of alternating plates, five or six in each. The tubercles are prominent, but decrease rapidly in size, the boss narrow and indistinctly crenulated, and the mammalon small, flattened, and imperforate. An indistinct circle of mammillated granules surrounds each tubercle. They unite to form a sinuous double series between the rows of tubercles. Between the larger granules are scattered irregularly numerous small granules that are crowded together along the central line of the interambulacra.

The apical system is slightly convex, the periproct interfering but little with the regularity of the curved surface. The periproct is subcircular, with a flangelike rim. The plates are decorated with oval granules arranged in radial rows extending from the opening of each genital plate and unite with corresponding rows of adjacent plates at the suture.

The peristome is small, being one-third of the transverse diameter of the test. Ten weak incisions divide the edge into lobes that are nearly of equal size.

Related forms.—This species is quite distinct from *Salenia texana* or *S. tumidula*, and at the same time does not admit of reference to any of the European species. It is most closely related to *S. tumidula*, but is more compressed, has a differently shaped and decorated apical system, and has round and mammillated granules in the miliary space, whereas those of *S. tumidula* are characteristically oval.

Locality.—Timber Creek, near Vincentown, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collections.—Academy of Natural Sciences of Philadelphia (1446); American Museum of Natural History, New York.

Suborder ARBACINA.

Family HEMICIDARIDÆ.

Genus HYPODIADEMA Desor.

Hypodiadema elegans Clark, n. sp.

Plate XIV, figures 2a–b.

Determinative characters.—Test small, moderately inflated, slightly tumid above the ambitus. Ambulacra narrow, nearly straight, with small perforate, crenulate tubercles diminishing in size from the ambitus aborally. Interambulacra broad, with moderately large tubercles perforate and crenulate. Apical system prominent, genital plates large, forming a periproctal ring; ocular plates small, elevated.

Dimensions.—Diameter 13.5 millimeters.

Description.—Only a single specimen of this species has been found. The abactinal and central portions of the test are well preserved, but the actinal surface is covered. The delicately sculptured test is small, somewhat inflated above. The ambulacra are nearly straight and narrow. The small primary tubercles at the ambitus are perforate and crenulate, but diminish in size toward the apical system.

The interambulacra are broad, the primary turbercles large, crenulate, and perforate, the depressed areolas being surrounded by a circle of granules. The miliary space is narrow, except toward the apical system, where it is large on the abutting plates. The apical system is elevated and pronounced. The large genitals which form the periproctal ring are perforated, the madreporite having two large openings. The oculars are small and elevated.

Locality.—Junction of Muddy and Clear forks of Little Missouri River, 3 miles west of Murfreesboro, Pike County, Ark.

Geologic horizon.—Trinity sand of the Comanche series, Cretaceous.

Collection.—U. S. National Museum (31196).

Genus GONIOPYGUS Agassiz.

Goniopygus zitteli Clark.

Plate XIV, figures 3a–c; Plate XV, figures 1a–h.

Goniopygus zittelli Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Goniopygus zittelli Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Goniopygus zittelli Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 53, 54, Pl. XVIII, figs. 2a–d; Pl. XIX, figs. 1a–e.
Goniopygus zitteli Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 155.

Determinative characters.—Test subconical, circular in outline; upper surface elevated; base flattened. Ambulacra broad, with a double row of alternating tubercles, 18 to 20 in each series; poriferous zones, with a double row of pores, multiplied at the peristome. Interambulacra broader than the ambulacra, with a double row of primary tubercles, 10 to 12 in each row. Apical system prominent, compact. Peristome large, with shallow incisions.

Dimensions.—Diameter 25 to 38 millimeters; height 15 to 25 millimeters.

Description.—All specimens examined by the writer have a distinctly subconical form that is highly characteristic. The upper surface is very much elevated, while the lower is flat and slightly depressed around the peristome.

The ambulacra are broad, increasing regularly in width from the apical disk to the ambitus, beyond which they decrease toward the peristome. There is a double row of 18 to 20 tubercles in each area that rapidly increase in size from the apical system downward. The pores are arranged in a double row on each poriferous zone, except in the vicinity of the peristome, where they become suddenly increased in number.

The interambulacra are about one and one-half times the width of the ambulacra, and each contains a double row of large tubercles, 10 to 12 in each series. These tubercles are considerably larger than those of the ambulacral area, and have wide circular areolas, smooth bosses, and imperforate mamelons. On the base the tubercles of all the areas are of nearly equal size.

The miliary space is wide, very nearly smooth in the upper portions of the column, and sparsely covered with granules toward the peristome.

The apical system is large and compact, the elongated genital plates giving it a star-shaped appearance. The well-defined ocular plates, wedged into the interspaces, make the entire outline subpentagonal. Each genital plate is angular at the outer extremity and perforated. On the inner edge of the same there is a semicircular depression, in the center of which is a small mammillated tubercle.

The peristome is large, covering quite one-half the diameter of the base. It is divided into ten lobes by ten shallow incisions.

Related forms.—The species shows many points of similarity to *Echinus patagonensis*, described by D'Orbigny in 1842, from the Tertiary of southern Patagonia. The margin of D'Orbigny's species is sharper and its apical system of somewhat different shape; moreover, if properly referred to the Tertiary, it is undoubtedly a different form. *Echinus andinus*, from the desert of Atacama, described by Philippi in 1860, is likewise closely allied to *G. zitteli*, although more conical and presenting a different surface decoration of the plates. *Goniopygus major*, from the Cenomanian of Europe, is similar in many particulars, although the pores are not increased around its peristome as in *G. zitteli*, and its apical system is more compact.

Locality.—Round Rock (type) and Spanish Oak branch, Williamson County, Tex.

Geologic horizon.—Edwards limestone of Fredericksburg group, Comanche series, Cretaceous.

Collections.—U. S. National Museum (12234); Texas Geological Survey.

Genus LEPTARBACIA Clark, n. gen.

Test small, circular in ambital outline, subhemispherical, upper surface depressed, lower surface flat. Ambulacral plates are simple primaries near the apical system and compound at the ambitus. Compound plates consist largely of one primary and three demiplates, two above and one below. Interambulacra with large plates and with six rows of small perforated and crenulated tubercles on lower surface which become reduced. Peristome of medium size. Periproct small.

LEPTARBACIA ARGUTUS Clark, n. sp.

Plate XVI, figures 1a–f.

Determinative characters.—Test small, depressed above, flat below, apical system of medium size, periproct nearly circular. Ambulacra straight, rather wide at ambitus and on lower surface, plates compound except near apical system, generally composed of one primary and three demiplates, some plates with one primary and two demiplates. Interambulacra with long bare median areas on upper surface, approaching ambitus, and on lower surface six rows of small perforated and crenulated tubercles.

Dimensions.—Diameter 20 millimeters; height 12 millimeters.

Description.—The single specimen of this species is small, with depressed upper surface and nearly flat below. It is somewhat depressed near the peristome.

The ambulacra are narrow, increasing in width from the apical system to the ambitus, beyond which they decrease in width toward the peristome. There is a double row of about thirty tubercles in each area, which become quite indistinct toward the apical disk. The pores are arranged in an irregular simple series in each poriferous zone.

The interambulacra are about three times the width of the ambulacra, and each contains from the ambitus to the peristome six rows of small perforated and crenulated tubercles, the central row of tubercles of each half continuing to the apical system, although gradually becoming less distinct as the latter is approached. The miliary space is covered with small granules.

The apical system is small, the genital plates being somewhat larger than the ocular, but rarely projecting farther than the latter. The periproct is small and slightly subcentral.

The peristome is apparently of medium size but is not well enough preserved to show its characteristic features.

Locality.—Fort Worth, Tex.

Geologic horizon.—Washita group of the Comanche series, Cretaceous.

Collection.—Johns Hopkins University (T 3004).

Suborder DIADEMINA.

Family ORTHOPSIDÆ.

Genus ORTHOPSIS Cotteau.

ORTHOPSIS PLANULATA Clark, n. sp.

Plate XVI, figures 2a–c.

Determinative characters.—Test small, depressed, circular in ambital outline, upper surface flattened, lower surface concave. Ambulacra narrow, pore pairs simple, primary tubercles small. Interambulacra broad, with several rows of vertical primary tubercles slightly larger than the ambulacra. Peristome of medium size.

Dimensions.—Diameter 28 to 32 millimeters; height 10 to 12 millimeters.

Description.—The species is represented by two specimens embedded in a single mass of indurated marl, one showing the adoral and the other the aboral surface, the former containing a number of spines. The test is relatively small, much depressed, the upper surface being distinctly flat, except directly at the apical system, which is slightly elevated. The under surface is concave. The ambulacra are narrow and bear two rows of small perforate, uncrenulated tubercles that become indistinct toward the apical system. The plates are simple primaries on the upper surface, but from just above the ambitus to the peristome two of the primaries commonly combine, the suture passing through the interporiferous tubercle. The poriferous zones bear a straight uniserial series of pores.

The interambulacra are broad, with six rows of perforate, uncrenulated tubercles on the under surface which are much reduced on the upper surface.

The peristome is of moderate size.

Locality.—Cut on Bonham road, southeastern edge of Denison, Tex.

Geologic horizon.—Grayson marl member of the Denison formation, of Washita group, Comanche series, Cretaceous.

Collection.—Johns Hopkins University (T 3005).

ORTHOPSIS OCCIDENTALIS Cragin.

Plate XVII, figures 1a–g.

Orthopsis occidentalis Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., pp. 160, 161, Pls. XXV, figs. 1–3; XXVII, fig. 2.

Determinative characters.—Test large, depressed, slightly pentagonal in ambital outline, upper surface tumid, lower surface concave; five perforated genitals, one a large madreporite, some of the oculars reaching the periproctal margin. Ambulacra narrow, straight; pore pairs in simple, straight series; primary tubercles small, perforate, and smooth; interambulacra broad with several vertical rows of small primary tubercles similar to the ambulacra. Peristome of medium size.

Dimensions.—Diameter 57 millimeters; height 33 millimeters.

Description.—The test is large, somewhat depressed, and slightly pentagonal in ambital outline. The upper surface is tumid directly above the ambitus, while the lower surface is concave.

The ambulacra are very narrow. Two rows of small primary perforated and uncrenulated tubercles extend from the peristome to the apical disk. The plates are simple primaries on the upper surface, but from the ambitus to the peristome two of the primaries generally combine, the suture passing through the interporiferous tubercle. The pores occur in simple series in the narrow poriferous zones.

The interambulacra are much broader than the ambulacra, with six rows of primary tubercles similar to those in the ambulacra. All of the tubercles about equal in size below the ambitus but all except the middle series of each row of plates gradually disappear above the ambitus, the latter alone continuing to the apical disk.

The peristome is of medium size with moderately developed incisions. The periproct is relatively large, the plates of the apical system being narrow.

Locality.—Sierra Blanca Mountain, near El Paso, Tex.

Geologic horizon.—Washita group of the Comanche series, Cretaceous.

Collection.—Geological Survey of Texas.

Family DIADEMATIDÆ.

Genus PSEUDODIADEMA Desor.

Pseudodiadema texanum (Roemer).

Plate XVIII, figures 1a–i.

Diadema texanum Roemer, 1852, Die Kreidebildungen von Texas, p. 82, Pl. X, fig. 5.
Pseudodiadema texanum Desor, 1858, Synopsis des échinides fossiles, p. 72.
Diadema texanum Gabb, 1859, Catalogue of invertebrate fossils of the Cretaceous formation, p. 19.
Pseudodiadema texanum Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 2.
Pseudodiadema roemeri Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 75.
Pseudodiadema texanum Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Pseudodiadema texanum Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 47, 48, Pls. XIII, figs. 2a–n; XIV, figs. 1a–g.
Pseudodiadema texanum Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., pp. 161, 162.
Pseudodiadema texanum Hill and Vaughan, 1898, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, Pl. LIII, figs. 3a, 3b.
Pseudodiadema texanum Hill, 1901, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, Pl. XXVII, figs. 3a, 3b.

Determinative characters.—Test small, circular, depressed; sides inflated; upper and lower surfaces about equally flattened. Ambulacra narrow, with two rows of primary tubercles, 11 or 12 in each row; poriferous zones narrow, pores uniserial. Interambulacra wide, with two rows of primary tubercles of larger size than those of the ambulacra. Peristome wide, covering nearly one-half the diameter of the test. Periproct subcircular, with deep incision in right anterior ambulacrum.

Dimensions.—Diameter 5 to 12 millimeters; height 8 to 22 millimeters.

Description.—This form, described by Roemer in 1852 as *Diadema texanum*, was properly assigned by Desor to the genus *Pseudodiadema*.

The test is circular, very much depressed on both the upper and lower surfaces and inflated at the sides.

The ambulacra are narrow and lanceolate. They bear two rows of tubercles, 11 or 12 in each row, that decrease rapidly in size from the ambitus to the poles. The areolas are circular, the bosses stout and prominent, the mamelons distinctly perforated. Small secondary tubercles are irregularly dispersed between the rows of primary tubercles. A few scattered granules surround the same. The poriferous zones are uniserial throughout, though the pores show a slight tendency to increase at the peristome.

The interambulacra are about twice the width of the ambulacra. There are two rows of primary tubercles, 9 or 10 in each row, that decrease in size from the ambitus to the poles. The areolas are depressed, circular, and distinctly outlined, the bosses elevated and deeply crenulated, the mamelons large and deeply perforated. Small secondary tubercles surround the primary tubercles, between which are interspersed minute granules.

The peristome is wide, covering nearly one-half of the diameter of the test. Ten incisions produce well-defined lobes at regular intervals. The periproct is large and subcircular, with a deep incision in the right anterior ambulacrum.

Related forms.—Both Roemer and Desor mention the similarity of this species to *P. tenue*, of the Cenomanian of Europe, from which, however, it is separated by its smaller tubercles and more numerous granules.

Localities.—Near Fredericksburg and in San Saba Valley (type), Barton Creek between Oatmanville and Bee Caves (figured specimen), near Austin and many other places in Texas.

Geologic horizon.—Glen Rose limestone of Trinity group and Comanche Peak limestone of Fredericksburg group, Comanche series, Cretaceous.

Collections.—U. S. National Museum (31197); Johns Hopkins University.

Pseudodiadema diatretum (Morton).

Plate XIX, figures 1a–f.

Cidaris diatretum Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 294.
Cidarites diatretum Morton, 1834, Synopsis Organic Remains Cretaceous, p. 75, Pl. X, fig. 10.
Cidaris diatretum Bronn, 1848, Index palæontologicus, vol. 1, p. 298.
Pseudodiadema diatretum Desor, 1858, Synopsis des échinides fossiles, p. 73.
Cidaris diatretum Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 18.
Pseudodiadema diatretum Cotteau, 1862–1867, Paléontologie française, vol. 7, p. 519.
Pseudodiadema diatretum Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 2.
Pseudodiadema diatretum Conrad, 1868, Geology of New Jersey, appendix, p. 722.
Cidaris clavigera Credner, 1870, Deutsche geol. Gesell. Zeitschr., vol. 22, p. 218.
Cidaris sceptrifera Credner, 1870, Deutsche geol. Gesell. Zeitschr., vol. 22, p. 218.
Pseudodiadema diatretum Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 75.
Pseudodiadema diatretum Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Pseudodiadema diatretum Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 46, 47, Pl. XIII, figs. 1a–f.
Pseudodiadema diatretum Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 6.
Pseudodiadema diatretum Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 285–286, Pl. IX, figs. 1–6.

Determinative characters.—Test circular, convex below, sides inflated. Ambulacra wide, sinuous, with two rows of tubercles that are large at the ambitus and decrease toward the poles; primary tubercles and several irregular rows of secondary tubercles. Peristome narrow, about one-third the diameter of the test.

Dimensions.—Diameter 30 to 37 millimeters; height 12.5 to 15 millimeters.

Description.—The specimens vary greatly in size, the full-grown forms being moderately large. The sides are inflated.

The ambulacra are wide, slightly raised, and furnished with two rows of tubercles, thirteen to fourteen in each row. They are large and prominent at the ambitus but decrease gradually toward the poles. The broad areolas, that are sharply depressed in their marginal portions, are striated by faint radial ridges on the outer parts. At the upper and inner angle of each plate is a small secondary tubercle, while irregularly scattered over the other portions of the plates are smaller tubercles, and between them minute granules. The poriferous zones are slightly flexed, the pores of each plate being disposed in curved form about the margin. Although there are generally three pairs of pores at each plate, four pairs are not infrequent near the ambitus.

The interambulacra are about one and one-half times the width of the ambulacra, and have two rows of tubercles somewhat larger than those of the latter. There are, in addition, several irregular rows of secondary tubercles, of various sizes, that are most numerous between the rows of primary tubercles and the poriferous zones. Sparsely scattered over the interambulacral space are flattened granules.

The primary tubercles of both the ambulacra and interambulacra have wide circular areolas, elevated and deeply crenulated bosses, and distinctly perforated mamelons.

The peristome is narrow, reaching scarcely one-third the diameter of the test. The incisions of the margin are weak.

The discal opening is subpentagonal.

Related forms.—This species resembles in some particulars *Pseudodiadema ornatum* Goldfuss of the Cretaceous of Europe, but the latter form has a different arrangement of the secondary tubercles and granules and lacks the radial striation upon the areolas.

Localities.—Gloucester (type), Timber Creek, and Vincentown, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collections.—Academy of Natural Sciences of Philadelphia (1471); New Jersey Geological Survey; American Museum of Natural History, New York.

Genus HETERODIADEMA Cotteau.

Heterodiadema ornatum Clark, n. sp.

Plate XVIII, figures 2a–f.

Determinative characters.—Test small, subconical, ambitus tumid, aboral surface depressed, lower surface convex; apical opening large; ambulacral plates with two vertical rows of small

perforated and crenulated tubercles, pore pairs in simple series doubling toward the peristome; interambulacral plates with two rows of primary tubercles but slightly larger than the ambulacral. Peristome small.

Dimensions.—Diameter 23 millimeters; height 11.5 millimeters.

Description.—The single specimen representing this species is small, subconical, depressed on the aboral surface but tumid at the ambitus. It is apparently distinctly convex on the adoral surface.

The ambulacra are moderately narrow, with two rows of small, primary, perforate, and crenulate tubercles. The pore pairs when seen are simple. The plates are compound, the sutures being very indistinct.

The interambulacra are much wider than the ambulacra and bear two rows of primary tubercles which are similar to the ambulacral. The posterior interambulacrum is deeply incised and depressed near the apical system which intrudes far into it.

The large aboral scar indicates an apical system of considerable size.

Locality.—Fort Worth, Tex.

Geologic horizon.—Washita group of the Comanche series, Cretaceous.

Collection.—Johns Hopkins University (T 3006).

Genus COTTALDIA Desor.

Cottaldia rotula Clark, n. sp.

Plate XX, figures 1a–d.

Determinative characters.—Test small, tumid, subhemispherical, aboral and adoral surfaces somewhat depressed; apical system small; ambulacral plates crowded with irregular rows of small primary tubercles, perforate and noncrenulate, pore pairs in simple series. Interambulacral plates with numerous small irregularly disposed tubercles; peristome small.

Dimensions.—Diameter 15 millimeters; height 12.5 millimeters.

Description.—The test is small, much inflated at the ambitus, subhemispherical. The aboral surface is slightly depressed and the adoral surface more so.

The ambulacra are narrow, with four rows of very small, perforate, and uncrenulate tubercles at the ambitus. The narrow poriferous zones are uniserial. The compound plates are composed of three primary plates with very indistinct sutures.

The interambulacra are wide, the plates being low and slightly bent. A row of seven small tubercles crosses each plate nearly horizontally at the ambitus but becomes reduced in number toward the poles. These tubercles are similar in character to those on the ambulacra.

The apical system and peristome are not preserved on the specimens examined.

Locality.—Shoal Creek, Travis County, Tex.

Geologic horizon.—Buda (Shoal Creek) limestone of the Washita group, Comanche series, Cretaceous.

Collection.—Johns Hopkins University (T 3007); U. S. National Museum.

Genus HEMIPEDINA Wright.

Hemipedina charltoni Cragin.

Hemipedina charltoni Cragin, 1894, Colorado Coll. Studies, vol. 6, pp. 41, 47, 50, 51.

Description.—Cragin describes this species as follows:

Test small, round-pentagonal, arched above, concave below; apical disk and periproct moderately broad; peristome considerably smaller in proportion to the test than in *Pseudodiadema texanum* Roemer; pore-belts straight, the pores somewhat elongated in the direction of the belt, the pore pairs simple throughout and somewhat oblique; ambulacral areæ half as broad as the interambulacral, each ornamented with two rows of primary tubercles that are somewhat smaller than those of the row of largest tubercles on the interambulacral areæ, each primary tubercle being subtended by an irregularly polygonal string of smaller (secondary) ones; interambulacral areæ with six rows of primary tubercles, these being much larger in the middle row of each semiambulacrum than in the others, the primaries subtended by secondaries for the most part in polygonal strings; surface of test closely granulated in the intervals between tubercles on both ambulacral and interambulacral areæ.

No figures are given and the incompleteness of the description leave some question as to whether the reference of this form to Hemipedina is correct.

Dimensions.—Diameter 25 millimeters; height 11 millimeters; width of peristome 7 to 8 millimeters; width of periproct 3.5 millimeters.

Locality.—About a mile east of Denison, Grayson County, Tex.

Geologic horizon.—Main Street limestone member of the Denison formation of Washita group, Comanche series, Cretaceous.

Collection.—Baylor University.

Family DIPLOPODIIDÆ.

Genus DIPLOPODIA McCoy.

Diplopodia taffi Cragin.

Plate XX, figures 2a–e.

Diplopodia taffi Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., pp. 148, 149, Pl. XLVI, fig. 3.

Determinative characters.—Test large, subcircular, depressed; lower surface flattened; ambulacra with two vertical rows of primary tubercles perforate and crenulate, slightly smaller than the interambulacral tubercles, pairs of pores biserial above the ambitus toward the apical system and at the peristome, iniserial below the ambitus; interambulacral plate with eight rows of primary tubercles at the ambitus; peristome small with well-marked incisions.

Dimensions.—Diameter 59 millimeters; height 26 millimeters.

Description.—This very beautiful species is one of the largest in the Lower Cretaceous. It is represented by a number of specimens although far less common than *Cyphosoma texanum*, with which it is found associated.

The test is depressed and slightly pentagonal in outline. The lower surface is flattened, the sides somewhat inflated, and the upper surface slightly elevated.

The ambulacra are of moderate width, with two vertical rows of perforate and crenulate primary tubercles, which are slightly smaller than the interambulacral tubercles. The pore pairs are biserial from the ambitus above toward the apical system and at the peristome, but uniserial from the ambitus toward the peristome.

The interambulacra are broad, with six rows of large and two of small primary tubercles at the ambitus, the small tubercles, one row on each side outside the large tubercles, being confined to that region. The outer rows of large tubercles likewise do not reach the peristome and apical system. A broad and somewhat depressed area follows the median section of the ambulacra.

The apical system is not large and its rays penetrate deeply the interambulacra.

The peristome is small, with ten rather deep branchial incisions.

Related forms.—This species shows some similarity to *D. streeruvitzi*, but is not quite as much elevated aborally.

Localities.—North San Gabriel River, 3 miles above Georgetown (type), Benbrook, Tarrant County, and Blum, Hill County, Tex.

Geologic horizon.—Comanche Peak limestone of Fredericksburg group, Comanche series, Cretaceous.

Collections.—Geological Survey of Texas; U. S. National Museum.

Diplopodia streeruvitzi Cragin.

Plate XX, figures 3a–c.

Diplopodia streeruvitzi Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., pp. 147, 148, Pl. XXIV, fig. 11, Pl. XXV, figs. 9–10.

Determinative characters.—Test medium size, subcircular, depressed, upper and lower surfaces flattened; ambulacral plates with two vertical rows of primary tubercles, pairs of pores simple except toward apical system and peristome where they are biserial; interambulacral plates with six to eight vertical rows of primary tubercles at the ambitus; peristome small.

Dimensions.—Diameter 25 to 50 millimeters; height 12 to 18 millimeters.

Description.—This species is not numerous, and the known forms are confined to El Paso County, Tex. The test is very nearly circular in ambital outline, is depressed, and is distinctly flattened both adorally and aborally.

The ambulacra are of moderate width with two vertical rows of perforate and crenulate primary tubercles of about the same size as the interambulacral tubercles. The poriferous zones are wide above the ambitus but narrow at the ambitus and below until near the peristome. The pore pairs are biserial aborally. There is much crowding of the pore pairs at the peristome.

The interambulacra are wide with six or eight rows of primary tubercles similar to those of the ambulacra. The outer rows are somewhat irregular in distribution and gradually disappear aborally.

The apical system is of medium size. The peristome is small.

Localities.—Sierra Blanca peaks (type) and near Kent, El Paso County, Tex.

Geologic horizon.—Washita group of the Comanche series, Cretaceous.

Collections.—Geological Survey of Texas; U. S. National Museum.

Family CYPHOSOMATIDÆ.

Genus CYPHOSOMA Agassiz.

Cyphosoma hilli Clark.

Plate XIX, figures 2a–g.

Pseudodiadema hilli Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Diplopodia hilli Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Diplopodia hilli Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 50, 51, Pl. XVI, figs. 2a–g.
Diplopodia hilli Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 147.

Determinative characters.—Test subpentagonal, depressed; sides inflated; upper and lower surfaces flattened. Ambulacra prominent, straight, with two rows of primary tubercles, twelve or thirteen in each row; poriferous zones narrow, with slight increase in width toward the apical system; pores in single pairs below but biserial on the upper surface. Interambulacra with two rows of primary tubercles of equal size with those of the ambulacra. Peristome narrow, circular. Discal opening broad, pentagonal.

Dimensions.—Diameter 20 millimeters; height 8 millimeters.

Description.—The test has a subpentagonal outline, the projecting ambulacra occupying the angles. It is depressed on both the upper and lower surfaces, the latter becoming somewhat concave toward the peristome. The sides are moderately inflated.

The ambulacra are broad, very prominent, and furnished with two rows of large tubercles, twelve or thirteen in each row, that decrease rapidly from the ambitus toward the apical system and peristome. The poriferous zones are narrow and lanceolate. The pores are arranged in single pairs on the lower surface, but from the ambitus to the apical system are increased slightly in number, and near the apical system become biserial. The interambulacra are narrow and appear flattened as compared with the slightly projecting ambulacra. They are provided with two rows of primary tubercles of equal size with those of the ambulacra. There are ten or eleven in each row. The areolas are narrow, circular, and elevated, the bosses prominent and distinctly crenulated, and the mamelons deeply perforated. The tubercles are somewhat widely separated and the intervening space is covered with small secondary tubercles and sparsely scattered granules.

The peristome is broad, depressed, and circular. It is divided by ten incisions into well-defined lobes, those of the ambulacra broader and extending farther into the opening than the others.

The discal opening is pentagonal, the angles occurring at the point of the medial suture of the interambulacra.

This species which was earlier referred to Diplopodia has been shown to belong to the genus Cyphosoma. Better material has furnished specimens in which the morphology of the ambulacra demiplates can be clearly seen.

Related forms.—The species is not unlike *C. texanum*, from which, however, it is separated by its smaller size, subpentagonal form, and two instead of four rows of primary tubercles.

Locality.—Austin, Tex.

Geologic horizon.—Austin chalk, Upper Cretaceous.

Collections.—U. S. National Museum (8311); Johns Hopkins University.

Cyphosoma texanum Roemer.

Plate XXI, figures 1a–g.

Diadema texanum Roemer, 1849, Texas, p. 392.
Cyphosoma texanum Roemer, 1852, Die Kreidebildungen von Texas, p. 82, Pl. X, fig. 6.
Cyphosoma texanum Conrad, 1857, in Hall's U. S. and Mex. Boundary Survey Rept., vol. i, pt. 2, p. 145, Pl. I, fig. 3.
Phymosoma texanum Desor, 1858, Synopsis des échinides fossiles, p. 90.
Cyphosoma texanum Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 18.
Cyphosoma texanum Gabb, 1869, Geol. Survey California, Paleontology, vol. 2, p. 276.
Pseudodiadema texanum Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 75.
Diplopodia texanum Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Diplopodia texanum Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 47, 48, Pl. XV, figs. 1a–f; Pl. XVI, figs. 1a–d.
Cyphosoma texana Aguilera, 1893, Datos para la geología de Mexico, p. 26.
Diplopodia texana Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 149.
Diplopodia texanum Cragin, 1894, Colorado Coll. Studies, vol. 5, p. 47.
Cyphosoma texana Aguilera, 1897, Inst. geol. México Bol., Nos. 4, 5, and 6, p. 21.
Diadema texana Böse, 1899, Inst. geol. México Bol., No. 13, p. 11.
Cyphosoma texana Böse, 1899, Inst. geol. México Bol., No. 13, p. 11.

Determinative characters.—Test large, subcircular; sides inflated; upper surface elevated; lower surface depressed, concave. Ambulacra prominent, with two rows of primary tubercles; poriferous zones broad above, narrow below; pores uniserial from near peristome to ambitus, beyond which to the apical system they are biserial. Interambulacra wide, with four rows of primary tubercles at the ambitus, which become reduced to two at the pores. Peristome wide, about two-fifths the diameter of the test. Periproct large, subpentagonal.

Dimensions.—Diameter 15 to 20 millimeters; height 8 to 20 millimeters.

Description.—This species was first described by Roemer in 1849 as *Diadema texanum*, but subsequently, in 1852, was referred to Cyphosoma.

The test is large, subcircular, and elevated. The sides are inflated and the aboral surface elevated and convex. The base is depressed and concave.

The ambulacra are broad and lanceolate. They have two rows of primary tubercles, fourteen or fifteen in each series, that are large at the ambitus and decrease gradually toward the poles. A circle of scattered granules surrounds the narrow areolas. The poriferous zones are broad upon the upper surface, but below the ambitus are very much narrowed. The pores are uniserial below the ambitus except directly at the peristome, where they become greatly increased. From the ambitus to the apical system they are biserial.

The interambulacra are about one and one-half times the width of the ambulacral at the ambitus. There are four rows of primary tubercles at the ambitus which become reduced to two in the vicinity of the apical system and peristome. In the center of the column the tubercles of the four rows are of about equal size, but those of the outer rows become much more rapidly reduced in size toward the poles. Small secondary tubercles are found on the outer margin of the plates, while irregularly scattered granules cover the space between the tubercles. A slight depression occurs along the line of the median suture.

The peristome is circular, but is broken by distinct incisions. Its diameter is about two-fifths that of the test. The periproct is large and subpentagonal.

The species was incorrectly referred earlier by the author to Diplopodia. A more thorough study of the much better material now available shows that this form is a Cyphosoma.

Related forms.—The species is very closely related to if not identical with *C. volanum* of the Washita group, but is somewhat taller and its four rows of primary tubercles on each interambulacrum are rather more definitely developed even on small specimens. It also shows a less

subpentagonal ambital outline. If the differences are more than varietal, then *C. texanum* must at all events be regarded as the ancestor of *C. volanum*.

Localities.—Fredericksburg and in the San Saba River valley (type), Leon Springs (figured specimen), near Austin, and many other places in Texas.

Geologic horizon.—Comanche Peak limestone of Fredericksburg group, Comanche series, Cretaceous.

Collections.—U. S. National Museum (9838); Boston Society of Natural History; Geological Survey of Texas; University of Iowa; Johns Hopkins University.

Cyphosoma volanum Cragin.

Plate XXI, figures 2a–b, 3.

Cyphosoma volanum Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 147.
Cyphosoma volanum Cragin, 1894, Colorado Coll. Studies, vol. 4, pp. 45, 47.
Cyphosoma volanum Hill, 1901, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 283.

Determinative characters.—Test small, subcircular; upper surface slightly elevated; lower surface depressed, concave. Ambulacra slightly prominent, with two rows of primary tubercles; poriferous zones sinuous; pores uniserial from peristome nearly to apical system. Interambulacra wide, each with two rows of primary tubercles, similar to those of ambulacra, adjoining which are smaller primary or secondary tubercles. Peristome small. Periproct large.

Dimensions.—Diameter 17.5 millimeters; height 8 millimeters.

Description.—This small species has a subcircular test with a slightly elevated upper surface. In general size and appearance the smaller specimens resemble *Pseudodiadema texanum*, but their other characters are very different.

The ambulacra are broad, with two rows of primary tubercles eight or nine in each row. The tubercles are large at the ambitus but become very small toward the apical system and peristome. The poriferous zones are narrow on the lower surface and at the ambitus, but widen above. They are sinuous. The pores are uniserial, although crowded toward the apical system.

The interambulacra are wide. There are two rows of primary tubercles similar to those of the ambulacra extending from the peristome to the apical system. Additional smaller primary or secondary tubercles, somewhat irregularly dispersed, adjoin the primary tubercles, while numerous granules occur on the surface of the plates.

The peristome is small with distinct branchial incisions. The periproct is large and subpentagonal.

Related forms.—Few if any differences serve to separate this form from *C. texanum* of the Fredericksburg group. In general it is lower and more depressed, is rather more subpentagonal in outline, and the four rows of tubercles on its interambulacra are less fully defined in many specimens. If more than a variety, it is certainly very closely related to *C. texanum* and descended from it.

Localities.—Below the Missouri, Kansas & Texas Railway bridge on Big Elm Creek, Benton County (type), and Denison, Grayson County, Tex.

Geologic horizon.—Denison formation of Washita group, Comanche series, Cretaceous.

Collection.—Geological Survey of Texas (A, B).

Genus COPTOSOMA Desor.

Coptosoma speciosum Clark.

Plate XIX, figures 3a–h.

Cyphosoma speciosum Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Coptosoma speciosum Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, p. 51.
Coptosoma speciosum Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 52, 53, Pl. XVIII, figs. 1–6.
Coptosoma speciosum Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 6.
Pseudodiadema speciosum Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 287–288, Pl. IX, figs. 7–14.

Determinative characters.—Test circular, inflated at the sides, flattened on the upper and lower surfaces. Ambulacra wide, with two rows of primary tubercles, twelve or thirteen in

each, that gradually diminish in size toward the poles; poriferous zones sinuous; pores uniserial. Interambulacra with two rows of tubercles slightly larger than those of the ambulacra. Peristome one-third the diameter of the test.

Dimensions.—Diameter 17 millimeters; height 9.5 millimeters.

Description.—This delicate species has a circular test with inflated sides. Both poles are flattened, the lower more than the upper.

The ambulacra are wide and prominent, and bear two rows of large tubercles, twelve or thirteen in each row. The areolas are nearly confluent above and below and are striated by irregular radiating ridges. The bosses are deeply crenulated, and the small mamelons are imperforate. Minute tubercles and granules irregularly surround the primary tubercles, occurring in greatest number along the central suture. The poriferous zones are slightly sinuous, the three pore pairs having a curved arrangement on each ambulacral plate.

The interambulacra are about one and one-half times as wide as the ambulacra. They have two rows of primary tubercles that are somewhat larger than those of the ambulacra. The areolas are very large and are confluent above and below. Throughout the greater part of the column the two rows approach each other, but toward the apical system they are widely separated from one another. The smaller tubercles are disposed in rows, with greater or less regularity, on either side of the primary series.

The peristome is narrow, occupying a little more than one-third of the diameter of the test. It has an irregular pentagonal outline. The discal opening is large and pentagonal in form.

Related forms.—This form is apparently closely related to *C. mortoni*, but is more elevated and does not exhibit granules between the pores.

Locality.—Timber Creek, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collection.—Academy of Natural Sciences of Philadelphia (1468).

Coptosoma mortoni (De Loriol).

Plate XXII, figures 1a–e.

Cyphosoma mortoni De Loriol, 1887, Recueil zool. Suisse, vol. 4, No. 3, pp. 389–391, Pl. XVII, figs. 2a–c.
Coptosoma mortoni Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, pp. 51, 52, Pl. XVII, figs. 1a–e.

Determinative characters.—Test circular, depressed. Ambulacra very wide, with two rows of primary tubercles, thirteen in each row, the three or four at the ambitus large and nearly confluent, but diminishing rapidly in size toward either pole; poriferous zones narrow, sinuous; pores uniserial, those of each pair separated by a granule. Interambulacra with two rows of tubercles, nine or ten in each row. Peristome very large.

Dimensions.—Diameter 12–15 millimeters; height about 6 millimeters.

Description.—The writer has been unable to obtain a specimen of this species, but the very full description and excellent figures given by De Loriol admit of its satisfactory identification. The description that follows is largely a translation of that given by De Loriol. The two specimens in the possession of De Loriol were so deformed that he could not determine the height accurately. The test is circular and depressed. The ambulacra are relatively very wide, almost as large as the interambulacra, and bear two rows of large tubercles, thirteen in each row. The first four or five tubercles from the apical system are far apart and very small. At the ambitus three or four of the tubercles are very large, with nearly confluent areolas, but rapidly diminish in size toward the lower surface, the last four or five being very small and with difficulty distinguished. The areolas, except at the ambitus, are not large. The bosses are finely crenulated and the mamelons small and imperforate. Upon the lower surface there are large mammillated granules which can be with difficulty distinguished from the primary tubercles. Each areola is also partially surrounded by a circle of small granules that occur most numerously near the line of the central suture. The granules are few in number on the upper surface. The poriferous zones are narrow, slightly sinuous, and composed of small pores without any increase between the apical system or peristome. A small granule is found between the pores of each pair.

The interambulacra bear two rows of primary tubercles that are similar to those of the ambulacra, but larger and less numerous. The lower surface is covered by large manumillated granules that can scarcely be distinguished from the tubercles, and also by numerous small ones. There are few granules on the upper surface. The peristome is large, with slight incisions.

Related forms.—The species is most closely related to *C. speciosum*, but in form and in several details of structure is unlike it. The presence of granules between the pores of the present species is apparently marked.

Locality.—Wahalak, Kemper County, Miss.

Geologic horizon.—Selma chalk, Upper Cretaceous.

Collection.—P. de Loriol, Switzerland.

Genus MICROPSIS Cotteau.

Micropsis lineatus Clark, n. sp.

Plate XXV, figures 1a–c.

Determinative characters.—Test medium size, slightly polygonal in ambital outline, tumid above, subhemispherical, slightly concave below. Apical system wanting. Ambulacra with compound plates covered with two rows of primary tubercles perforate and crenulate. Interambulacra with six rows of primary tubercles, which rapidly decline in size above the ambitus. Peristome small.

Dimensions.—Diameter 25.25 millimeters; height 12 millimeters.

Description.—The test is of medium size and slightly polygonal in ambital outline, with tumid upper surface. It is subhemispherical and slightly concave on the lower surface.

The ambulacra are narrow and covered with two vertical rows of perforate and crenulate primary tubercles. The poriferous zones are not sharply defined. The plates are compound, with a low primary adorally.

The interambulacra have six rows of primary tubercles which decline rapidly in size above the ambitus.

The peristome is small and with slight branchial incisions.

Locality.—Cut on Bonham road, southeast edge of Denison, Tex.

Geologic horizon.—Grayson marl member of the Denison formation, of Washita group, Comanche series, Cretaceous.

Collection.—U. S. National Museum (31198).

Suborder ECHININA.

Family TRIPLECHINIDÆ.

Genus PSAMMECHINUS Agassiz.

Psammechinus cingulatus Clark.

Plate XXII, figures 2a–i.

Psammechinus cingulatus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Psammechinus cingulatus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Psammechinus cingulatus Clark, 1893, U. S. Geol. Survey Bull. 97, p. 55, Pl. XX, figs. 1a–i.
Psammechinus cingulatus Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 6.
Psammechinus cingulatus Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 288–289, Pl. X, figs. 1–9.

Determinative characters.—Test small, hemispherical, with circular outline; sides inflated; upper surface elevated; base flattened and concave. Ambulacra wide, with two rows of primary tubercles, sixteen or seventeen in each series; poriferous zones depressed, triserial. Interambulacra about one and one-half times the width of the ambulacra; plates covered with numerous uncrenulate and imperforate tubercles. Peristome large, with ten deep incisions.

Dimensions.—Diameter 22 millimeters; height 12.5 millimeters.

Description.—This delicate form, of which two very imperfect specimens were examined by the writer, is hemispherical in shape, with circular circumference, inflated sides, elevated upper

surface, and flattened base. In the vicinity of the mouth opening the lower surface is depressed, producing a slight concavity.

The ambulacra are wide and composed of eighteen to twenty plates. The lower sixteen or seventeen of each series bear prominent tubercles that occur in a continuous line to the peristome. On either side of the primary tubercles are smaller ones of like shape. The three pore pairs are arranged in semicircular form, the two upper separated from the lower by one of the secondary tubercles.

The interambulacra are about one and one-half times as wide as the ambulacra and the plates are about fifteen in number. Each plate bears a large tubercle in the center, and irregularly arranged about it smaller tubercles of various sizes.

The peristome is large, with 10 deep incisions. The apical system is lacking, but the discal opening is large and pentagonal in form.

Related forms.—This unique species is quite unlike any hitherto described, and is readily characterized by the arrangement of the tubercles and pore pairs. As the only representative of the genus in American Cretaceous deposits it has especial interest.

Locality.—Timber Creek, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collection.—Academy of Natural Sciences of Philadelphia (1467).

Genus PEDINOPSIS Cotteau.

Pedinopsis symmetrica (Cragin).

Plate XXIII, figures 1a–h.

Dumblea symmetrica Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 150, Pl. XXXIV, fig. 12, Pl. XXV, figs. 4–7; Pl. XXVII, fig. 1.

Determinative characters.—Test medium size, subconical, inflated on the aboral surface, concave on the adoral surface, sides tumid. Ambulacra with several vertical rows of primary perforate tubercles, poriferous zones broad, pore pairs biserial. Interambulacra broad and low with many rows of primary tubercles similar to those of the ambulacra. Apical system small, madreporite large, posterior right-hand ocular reaches the periproct. Peristome small.

Dimensions.—Diameter 15 to 45 millimeters; height 12 to 33 millimeters.

Description.—The species referred by Cragin to a new genus which he named Dumblea is evidently a representative of the genus Pedinopsis. A specimen referred to J. W. Gregory of Glasgow was pronounced by him to be a typical Pedinopsis.

The test is of medium size, tumid, subconical, flattened and concave on the lower surface. The circular ambital outline is somewhat broken by the sutures between the ambulacra and interambulacra producing an imperfectly defined 15-lobed appearance.

The ambulacra are rather broad with well-defined poriferous zones. They are covered with two rows of primary tubercles in the smaller and four in the larger specimens. These tubercles are perforate and apparently plain or uncrenulate, although the state of preservation makes it uncertain as to whether delicate crenulation may not have existed.

The interambulacra are broad and low with many vertical rows of primary tubercles similar to those of the ambulacra. They diminish in number aborally.

The apical system is small, the madreporite being large and encroaching on the adjacent genitals. The posterior right-hand ocular reaches the periproct.

The peristome is small with well-marked branchial incisions. The periproct is oval.

Localities.—Sierra Blanca peaks (type) and near Kent, El Paso County, Tex.

Geologic horizon.—Washita group of the Comanche series, Cretaceous.

Collections.—Geological Survey of Texas; U. S. National Museum.

Pedinopsis pondi Clark.

Plate XXIV, figures 1a–d.

Pedinopsis pondi Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Pedinopsis pondi Clark, 1893, U. S. Geol. Survey Bull. 97, p. 57, Pl. XXI, figs. 1a–b; Pl. XXII, figs. 1a–c.

Determinative characters.—Test large, circular, inflated at the sides, convex on the upper surface. Ambulacra with six rows of tubercles at the ambitus, the two marginal rows complete and the four inner incomplete; poriferous zones broad, biserial. Interambulacra with 20 rows of tubercles at the ambitus, which become reduced to four at the margin of the peristome; tubercles small, equal, crenulate, and perforate. Peristome small, with distinct incisions.

Dimensions.—Diameter 88 millimeters; height 58 millimeters.

Description.—The very large specimen on which this species is established has portions of the test in a very perfect state of preservation. The test is large, circular, inflated at the sides, and convex on the upper surface. The lower surface is flattened, with a slight concavity in the region of the peristome.

The ambulacra are wide, and have at the ambitus six rows of tubercles, the two marginal rows alone continuing from the discal opening to the peristome. The four inner rows are incomplete, but of equal size with the outer. The tubercles are finely crenulated and perforated. The poriferous zones are broad and biserial, except on the lower surface, where the pore pairs become crowded together. Near the peristome they again broaden out and become greatly increased in number at the margin. The pores are small and round.

The interambulacra are broad and have twenty rows of tubercles at the ambitus, which become reduced to four at the peristome. The tubercles are of equal size with those of the ambulacra. Small mammillated granules are found scattered over both the ambulacral and interambulacral plates, together with a fine granulation covering the entire surface.

The peristome measures about seven-eighths of an inch in diameter. It has 10 distinct incisions in the interambulacra. The discal opening is partly outlined but is very indistinct.

This species is named for Edwin J. Pond, of the United States Coast and Geodetic Survey, by whom the specimen described by the writer was discovered.

Locality.—The south bank of Onion Creek, about one-fourth mile southwest of the crossing of the Austin and San Antonio wagon road, Travis County, Tex.

Geologic horizon.—Austin chalk, Upper Cretaceous.

Collection.—Johns Hopkins University (T 3008).

Subclass IRREGULARIA.

Order GNATHOSTOMATA.

Suborder HOLECTYPINA.

Family PYGASTERIDÆ.

Genus HOLECTYPUS Desor.

Holectypus planatus Roemer.

Plate XXV, figures 2a–f, 3a–c, 4, Plate XXVI, figures 1a–e.

Holectypus planatus Roemer, 1849, Texas, p. 393.
Holectypus planatus Roemer, 1852, Die Kreidebildungen von Texas, p. 84, Pl. X, fig. 2.
Holectypus planatus Shumard, 1852, Exploration Red River of Louisiana Rept., p. 211.
Holectypus planatus Giebel, 1853, Naturwiss. Ver. in Halle Jahresb., p. 373.
Holectypus planus Giebel, 1853, idem.
Holectypus planatus Conrad, 1857, U. S. and Mex. Boundary Survey Rept., vol. 1, pt. 2, p. 145, Pl. I, fig. 4.
Holectypus planatus Desor, 1858, Synopsis des échinides fossiles, p. 174.
Holectypus planatus Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 18.
Holectypus planatus Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 2.

Holectypus sp. Roemer, 1888, Pal. Abhandl. von Dames und Kayser, vol. 4, pt. 4, p. 9 (287), Pl. I (XXXI), figs. 6a–c.
Holectypus planatus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Holectypus planatus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Holectypus planatus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 58, 59, Pl. XXII, figs. 2a–f.
Holectypus charltoni Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 158, Pl. XXIV, figs 8, 9.
Holectypus planatus Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., pp. 159, 160.
Holectypus transpecosensis Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 160, Pl. XXVII, figs. 3–5.
Holectypus charltoni Cragin, 1894, Colorado Coll. Studies, vol. 5, p. 41.
Holectypus planatus Hill, 1901, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 226.

Determinative characters.—Test subcircular, subconical, flattened on the under surface. Ambulacra narrow, straight, and somewhat lanceolate, with six irregular rows of tubercles; poriferous zones somewhat straight, narrow, unigeminal. Interambulacra wide, plates numerous and narrow, each with a nearly horizontal row of small tubercles. Apical system small, the madreporite large. Peristome small, subcircular. Periproct large.

Dimensions.—Transverse diameter 12–70 millimeters; height 7–40 millimeters.

Description.—This very common form from the Cretaceous of Texas was first reported by Roemer in 1849, and was subsequently, in 1852, more accurately defined and figured by him. Although wide differences in outline and in the size and arrangements of the tubercles occur, they appear to be rather individual than specific. The majority of the specimens are subcircular; in the case of some, however, distinctly circular, while in that of others clearly pentagonal. The ambitus in some individuals is sharp, in others rounded, while the upper surface is distinctly elevated at the center with slightly tumid sides. The under surface is flat and slightly depressed in the vicinity of the peristome.

The ambulacra are narrow, straight, increasing in width toward the ambitus and somewhat lanceolate in form. The poriferous zones are narrow, the pores small and unigeminal. Six rows of small tubercles are found in the broader portion of the areas, which become reduced to four toward the apical disk and peristome.

The interambulacra are about three times the width of the ambulacra at the ambitus. The plates are narrow, each with a horizontal row of small tubercles, five or six in a row at the ambitus, but fewer above and below. Each tubercle has a small circular areola, crenulated boss, and perforated mamelon. The tubercles cover the greater portion of the plates, with minute granules interspersed between them. The tubercles are very much larger on the lower surface, and the difference in size shown between those of the ambulacra and interambulacra on the upper surface disappears.

The apical system is small. The five ovarial plates are all perforated; the madreporite is of large size and indistinctly separated from the other plates.

The peristome is small, with slight incisions that give a decagonal margin. The large oval peristome extends from the vicinity of the mouth to the ambitus.

Related forms.—The size of the adult forms is very variable, those found in the Washita group being larger than those found in the Trinity and Fredericksburg group. The individuals also vary in height. So many connecting forms can be found between the typical *H. planatus* and the species described as *H. charltoni* and *H. transpecosensis* by Cragin that they have been regarded as synonyms.

Localities.—Near Fredericksburg (type), Cow Creek, Travis County (figured specimens A and B); Denton County (figured specimen C); Shoal Creek, Austin (figured specimen D); San Antonio, Kent, and many other localities in Texas.

Geologic horizon.—Trinity, Fredericksburg, and Washita groups of the Comanche series, Cretaceous.

Collections.—U. S. National Museum (12236); Academy of Natural Sciences of Philadelphia; Boston Society of Natural History; Geological Survey of Texas; Johns Hopkins University (T 3008).

Suborder CLYPEASTRINA.

Family CLYPEASTRIDÆ.

Genus ECHINANTHUS Leske.

Echinanthus mortonis (Michelin).

Pygorhynchus mortonis Michelin, 1850, Rev. et mag. zoologie, vol. 2, p. 240.
Hardouinia mortoni D'Archiac and Haime, 1853, Foss. numm. de l'Inde, p. 214.
Echinanthus mortonis Desor, 1858, Synopsis des échinides fossils, p. 295.
Echinanthus mortonis Dujardin and Hupé, 1862, Hist. nat. zoophytes échin., p. 584.
Echinanthus mortonis Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 75.
Echinanthus mortonis Conrad, 1866, Check list, p. 22.
Echinanthus mortonis Quenstedt, 1872-1875, Petrefac. Deutsch., p. 692.

Description.—The author has been unable to examine a specimen of this species. Desor gives the following description:

Espèce remarquable entre tous les Echinanthus par sa forme élevée, conique, à peu près aussi large que longue, rappelant un peu les Pygurus par sa physionomie. Sommet ambulacraire légèrement excentrique. Pétales larges, pointus à leur extrémité, dépassant un peu la moitié de la distance entre le sommet et le bord. Périprocte grand, situé à mi-distance du sommet, à l'origine d'un large et profond sillon. Dessous concave. Péristome à peu près central, petit, entouré d'un floscelle très accusé.

D'Archiac and Haime proposed to make of this species the type of a new genus which they called Hardouinia. Notwithstanding the fact that the floscelle is somewhat more pronounced than in any of the other species Desor and others who examined the form considered that the characters were not sufficiently pronounced to justify a generic separation from Echinanthus.

Locality.—Pontotoc, Miss.

Geologic horizon.—Ripley formation, Upper Cretaceous. The reference of this form to the Tertiary by earlier authors is evidently incorrect.

Collection.—Unknown. Desor mentions its presence in the collection of Verneuil.

Genus SCUTELLASTER (?) Cragin.

?Scutellaster cretaceus Cragin.

Scutellaster cretaceus Cragin, 1895, Am. Geologist, vol. 15, pp. 90, 91.

Description.—The specimen on which this genus and species are based is so imperfect that it seems better to defer the acceptance of both until more diagnostic material is obtained. Cragin in a letter to the author says: "I fear it [Scutellaster] is not after all a new genus as I supposed when I described it as such."

Locality.—East slope of Shooks Run, Platt Avenue, Colorado Springs, Colo.

Geologic horizon.—Arenaceous shale of Fox Hills sandstone of Montana group, Upper Cretaceous.

Collection.—Colorado College.

Order ATELOSTOMATA.

Suborder ASTERNATA.

Family ECHINONEIDÆ.

Genus PYRINA Desmoulins emend. De Loriol.

Pyrina parryi Hall.

Plate XXVII, figures 1a–j.

Pyrina parryi Hall, 1857, U. S. and Mex. Boundary Survey Rept., vol. 1, pt. 2, p. 144, Pl. I, figs. 1–1d.
Pyrina parryi Gabb, 1859, Catalogue Invertebrate Fossils Cretaceous, p. 19.
Pyrina parryi Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 2.
Pyrina parryi Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.

Pyrina parryi Aguilera, 1893, Datos para la geología de México, p. 26.
Pyrina parryi Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Pyrina parryi Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 59, 60.
Pyrina bulloides Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 162.
Pyrina parryi Aguilera, 1897, Inst. geol. México Bol. Nos. 4, 5, 6, p. 215.
Pyrina parryi Bosé, 1899, Inst. geol. México Bol. No. 13, p. 11.

Determinative characters.—Test subpentagonal, broader anteriorly than posteriorly, inflated at the sides, flattened above and below. Ambulacra narrow, uniserial; both areas covered with minute tubercles.

Peristome large, elliptical, oblique. Periproct oval, supramarginal.

Dimensions.—Length 20 to 35 millimeters; width 18 to 30 millimeters; height 12 to 25 millimeters.

Description.—The test is regular and symmetrical, slightly pentagonal in outline, enlarged anteriorally, contracted posteriorly. The upper surface is convex, although somewhat flattened at the summit. The sides are inflated, the base flattened and slightly depressed in the vicinity of the peristome.

The ambulacra are narrow and lanceolate; the poriferous zones straight and depressed, the pores small, oval, and uniserial. The interambulacra are broad and less elevated than the ambulacra. Both the ambulacra and the interambulacra support numerous small tubercles that are larger and more distinct on the lower than the upper surface. Fine microscopic granules are disseminated between the tubercles.

The peristome is large, elliptical, and obliquely situated slightly in front of the center of the base. The periproct is oval and placed nearly in the center of the posterior margin. The apical system is small, composed of four genital plates, the large right antero-lateral modified to form the madreporite. The five small ocular plates are firmly wedged between the ovarial plates.

Related forms.—The species just described is the only representative of this genus from American strata and both in form and structural features admits of a ready separation from all European species. It presents some points of similarity with *Pyrina desmoulinsii* D'Archiac, but is broader posteriorly and less elevated. The many specimens of this common species which have come under the observation of the author show considerable variation, but are all regarded as representing a single species.

Localities.—Leon Springs (type), near San Antonio, Pilot Knob (Travis County), Kent, Sierra Blanca peaks, and many other localities in Texas.

Geologic horizon.—Fredericksburg and Washita groups, Comanche series, Cretaceous.

Collections.—U. S. National Museum (9854); Johns Hopkins University.

Family NUCLEOLITIDÆ.

Genus BOTRIOPYGUS D'Orbigny.

Botriopygus alabamensis Clark.

Plate XXIV, figures 2a–f.

Botriopygus alabamensis Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Botriopygus alabamensis Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 51.
Botriopygus alabamensis Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 60, 61, Pl. XXV, figs. 1a–f.

Determinative characters.—Test oblong; more or less depressed on upper surface, highest anteriorly; under surface concave. Ambulacra broad, lanceolate; poriferous zones subpetaloidal above. Interambulacral plates covered with numerous, irregularly distributed tubercles. Apical system anteriorly situated. Peristome small, oblique, forward of the center.

Dimensions.—Length 63 millimeters; width 54 millimeters; height 26 millimeters.

Description.—The single imperfectly preserved specimen of this species, although apparently lacking some of the characteristics of Botriopygus, is nevertheless referred to that genus. The test is oblong, considerably depressed on the upper surface, and concave on the base. The apex

of the upper surface is forward of the center, making the anterior margin full, the posterior flattened.

The ambulacra are broad and lanceolate. They contract appreciably just above the ambitus, giving to the poriferous zones a subpetaloidal form. The pores of the subpetaloidal portions are large and oval, those of the outer rows more elongated than those of the inner and acuminated on their inner margins. The pores of each pair are united by a furrow. The inner portions of the ambulacral plates are covered with tubercles, which in the broadest portion of the subpetaloidal areas reach five or six in number. Below the subpetaloidal areas the pores recede from the outer margin of the plates. Those of each pair are close together, small, and nearly round, and the plates also become broader.

The interambulacral plates are large and covered with numerous, irregularly arranged tubercles. A microscopic granulation covers the intertubercular space.

The position of the apical system is forward of the center of the upper surface, although none of the plates are preserved on the specimen examined. The peristome is small and obliquely placed slightly in front of the center of the base.

Related forms.—Under the name of *B. elevatus* Gabb describes a species from Peru that is not unlike *B. alabamensis* in many particulars. *B. alabamensis*, however, is larger, less rounded anteriorly, and has a more depressed posterior margin.

Locality.—Alabama.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—Academy of Natural Sciences of Philadelphia.

Genus ECHINOBRISSUS Breyn.

ECHINOBRISSUS ANGUSTATUS Clark, n. sp.

Plate XXVII, figures 2a–c.

Determinative characters.—Test small, subovate, rounded anteriorly, subquadrate posteriorly; upper surface elevated; apex forward of the center; base concave. Ambulacra lanceolate. Peristome small, excentric; periproct small in broad shallow sulcus, placed well posteriorly.

Dimensions.—Length 15.5 millimeters; width 14 millimeters; height 8.5 millimeters.

Description.—This small form is subovate in ambital outline, is rounded anteriorly and truncated posteriorly, giving a subquadrate effect. The upper surface is elevated and the lower concave.

The ambulacra are very indistinct on the type. The apical system is forward of the center but the individual plates are indistinguishable. The peristome is small, deeply depressed and excentric in front. The periproct is small in a broad shallow sulcus and placed well posteriorly.

Locality.—Shoal Creek, Tex.

Geologic horizon.—Buda (Shoal Creek) limestone of Washita group, Comanche series, Cretaceous.

Collection.—Johns Hopkins University (T 3009).

ECHINOBRISSUS EXPANSUS Clark.

Plate XXVIII, figures 1a–g.

Echinobrissus expansus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Echinobrissus expansus Clark, 1893, Johns Hopkins Univ. Circ., vol 12, No. 103, p. 52.
Echinobrissus expansus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 61, 62, Pl. XXVI, figs. 1a–g.
Echinobrissus expansus Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc. vol. 57, p. 6.

Determinative characters.—Test subquadrate, broader posteriorly, moderately convex on upper surface, concave on the base. Ambulacra narrowly lanceolate. Periproct large, supramarginal; anal sulcus broad, deep, extending from near the apex to the ambitus. Peristome large, situated in front of the middle of the base.

Dimensions.—Length 27 millimeters; width 27 millimeters; height 12 millimeters.

Description.—This typical Echinobrissus is of a moderate size, somewhat depressed above, and subquadrate in marginal outline. The posterior portion is broader than the anterior and distinctly lobed. The base is concave.

The ambulacral areas are narrowly lanceolate, and on the upper surface the poriferous zones are subpetaloidal. The inner rows of pores are round, the outer oval, with acuminated inner margins and obliquely placed. The interambulacral areas are formed of broad plates that bear numerous small perforated and mammillated tubercles. A microscopic granulation covers the miliary space.

The apical system is small and compact and the perforations of the genital plates distinct.

The peristome is large, excentric, situated at some distance in front of the center of the base. The periproct is large, acuminated on the upper margin, and placed in a broad, deep anal sulcus that extends from near the apical system to the posterior margin.

Related forms.—*Echinobrissus expansus* has few points that would closely ally it with any species of this genus hitherto described.

Locality.—Alabama or Mississippi.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—Academy of Natural Sciences of Philadelphia (1465).

Echinobrissus texanus Clark.

Plate XXVIII, figures 2a–f.

Echinobrissus texanus Clark, 1891, Johns Hopkins Univ. Circ., vol 10, No. 87, p. 76.
Echinobrissus texanus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Echinobrissus texanus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 62, 63, Pl. XXVI, figs. 2a–f.
Echinobrissus texanus Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 150.

Determinative characters.—Test ovate, rounded anteriorly, subquadrate posteriorly; upper surface convex, apex forward of the center; base concave. Ambulacra lanceolate, subpetaloidal. Apical system forward of the center. Peristome small, excentric. Periproct small, oval, in narrow sulcus that begins some distance below the apical disk.

Dimensions.—Length 18.75 millimeters; width 16.5 millimeters; height 9.5 millimeters.

Description.—The single specimen of this species is somewhat damaged on the sides, so that the ambital outline is not complete. It is ovate in form, broader posteriorly and subquadrate. The upper surface is convex, but more or less compressed. The lower surface is concave.

The ambulacra are narrowly lanceolate. The poriferous zones for a short distance from the apical system are subpetaloidal in form. The posterior ambulacra are much longer than the others, the unpaired ambulacrum being the shortest. The pores of each plate are oval and set at an angle to one another.

The interambulacral plates are large and covered with irregularly arranged tubercles. Between the tubercles a microscopic granulation covers the surface.

The apical system is small and situated forward of the apex. The individual plates can not be fully distinguished on the specimen examined. The peristome is apparently small, though somewhat obscured. It is situated forward of the center of the base.

The periproct is small, placed in a narrow sulcus that begins some distance posterior to the apical system.

Related forms.—*Echinobrissus texanus* is readily separated from *E. expansus* by its ovate form and the shape and size of the anal sulcus. It is unlike any European species.

Locality.—South bank of Colorado River, Austin, Tex.

Geologic horizon.—Austin chalk, Upper Cretaceous.

Collection.—U. S. National Museum (20266).

Genus TREMATOPYGUS D'Orbigny.

TREMATOPYGUS CRUCIFERUS (Morton).

Plate XXVIII, figures 3a–c; Plate XXIX, figures 1a–f.

Ananchytes cruciferus Morton, 1830, Am. Jour. Sci., 1st ser., vol. 18, p. 245, Pl. III, fig. 8.
Ananchytes cruciferus Morton, 1830, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, pp. 201, 202.
Nucleolites crucifer Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 294.
Nucleolites crucifer Morton, 1834, Synopsis Organic Remains Cretaceous, p. 75, Pl. III, fig. 15.
Nucleolites cruciferus Agassiz, 1840, Catalogus systematicus, p. 4.
Nuculites cruciferus Agassiz and Desor, 1847, Catalogue raisonné, p. 97.
Nuculites crucifer Bronn, 1848, Index palæontologicus, vol. 1, p. 818.
Nucleolites cruciferus D'Orbigny, 1850, Prodrome, vol. 2, p. 271, étage 22, No. 1197.
Pygorhynchus crucifer Ravenel, 1850, Am. Assoc. Adv. Sci. Proc., p. 160.
Trematopygus crucifer D'Orbigny, 1853–60, Paléontologie française, vol. 6, p. 387, Pl. CMLIII, figs. 10, 11; Pl. CMLXIII, figs. 1–5.
Echinobrissus crucifer D'Orbigny, 1854, Rev. et mag. zoologie, ser. 2, vol. 6, p. 25.
Nucleolites crucifer Desor, 1858, Synopsis des échinides fossiles, p. 262.
Nuculites crucifer Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Nuculites crucifer Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 2.
Nuculites crucifer Cook, 1868, Geology of New Jersey, p. 377.
Nuculites crucifer Conrad, 1868, Geology of New Jersey, App. A, p. 722.
Nuculites cruciferus Credner, 1870, Deutsche geol. Gesell. Zeitschr., vol. 22, p. 217.
Trematopygus crucifer Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Trematopygus crucifer Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Trematopygus crucifer Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 63, 64, Pl. XXVII, figs. 1a–i.
Trematopygus crucifer Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.
Trematopygus cruciferus Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 289–290, Pl. XI, figs. 1–9.

Determinative characters.—Test ovate, inflated at the sides and base and slightly contracted anteriorly. Ambulacra long, well defined; pores uniserial, prominent on the upper surface, indistinct on the base. Apical system situated anteriorly. Peristome large and oblique. Periproct large, oval, supramarginal.

Dimensions.—Length 18 to 20 millimeters; breadth 15 to 22 millimeters; height 10 to 14 millimeters.

Description.—This species is not uncommon at Timber Creek, N. J., where many very perfect specimens have been obtained. Its outline is ovate and very regular, lacking at the ambitus or apex any sharply defined angularity. The sides are highly inflated together with the outer portion of the base.

The ambulacra are long, lanceolate, and unequal; the posterior pair are the longest, the unpaired anterior one is the shortest. They do not produce any irregularity in the outline of the test beyond inconsiderable depressions in the immediate vicinity of the peristome. The poriferous zones are clearly marked on the upper surface, and the pore pairs are nearly horizontal, but toward the ambitus the pores become smaller, those of each pair nearer together, and the pairs obliquely situated at the lower, outer corner of each plate; near the peristome they again become larger and slightly increased in number.

The interambulacra are wide and composed of large plates that are bent in the middle. The surface is covered with irregular rows of tubercles that are perforated and mammillated. The miliary space is covered with numerous minute and irregularly distributed granules.

The apical system is small and anteriorly situated; the four genital plates are distinctly perforated; those of the anterior pair are much nearer together than those of the posterior.

The peristome is large, oblique, and placed somewhat forward of the center of the base. The periproct is large, oval, and acuminate at the upper extremity. It is situated in an anal sulcus that makes a marked indentation in the posterior margin, and is bordered by two well-defined ridges.

Related forms.—*Trematopygus cruciferus* (Morton) is a unique species that has no closely allied forms in either American or European deposits.

Locality.—The yellow limestone of Timber Creek and Vincentown (type), N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collections.—American Museum of Natural History, New York; Academy of Natural Sciences of Philadelphia (1464); Johns Hopkins University.

Family CASSIDULIDÆ.

Genus PYGURUS Agassiz.

?Pygurus geometricus (Morton).

Clypeaster sp. Morton, 1830, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, p. 202.
Clypeaster geometricus Morton, 1833, Am. Jour. Sci., 1st ser., vol. 24, p. 131, Pl. X.
Clypeaster geometricus Morton, 1834, Synopsis Organic Remains Cretaceous, p. 76, Pl. X, fig. 10.
Pygurus geometricus Agassiz and Desor, 1847, Catalogue raisonné, p. 141.
Clypeaster geometricus Bronn, 1848, Index palæontologicus, vol. 1, p. 312.
Pygurus geometricus D'Orbigny, 1850, Prodrome, vol. 2, p. 270.
Pygurus geometricus D'Orbigny, 1853–60, Paléontologie française, vol. 6, p. 313, Pl. CMXX, fig. 4.
Pygurus geometricus Desor, 1858, Synopsis des échinides fossiles, p. 313.
Clypeaster geometricus Gabb, 1859, Catalogue Invertebrate Fossils Cretaceous, p. 18.
Pygurus (?) *geometricus* Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Pygurus (?) *geometricus* Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 92, 93.
Pygurus (?) *geometricus* Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.

The type of this species was examined by the writer, but its state of preservation (that of a poor cast) is such that its generic relations can not be with certainty determined. Until further material is obtained it seems best to defer its recognition. Although originally described by Morton as a Clypeaster, it has been referred to the genus Pygurus by Agassiz, D'Orbigny, and Desor.

Locality.—Delaware and Chesapeake Canal, Delaware.

Geologic horizon.—Matawan formation, Upper Cretaceous.

Collection.—Academy of Natural Sciences of Philadelphia.

Genus CATOPYGUS Agassiz.

Catopygus oviformis Conrad.

Plate XXIX, figures 2a–f.

Catopygus oviformis Conrad, 1847, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 2, p. 39, Pl. I, fig. 9.
Nucleolites oviformis (Catopygus) Conrad, 1868, Geology of New Jersey, App. A, p. 722.
Catopygus oviformis Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Catopygus oviformis Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Catopygus oviformis Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 64, 65, Pl. XXVII, figs. 2a–f.
Catopygus oviformis Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.

Determinative characters.—Test ovate, broader posteriorly; upper surface nearly flat; apex posterior to apical disk. Ambulacra narrow, subpetaloidal. Interambulacra wide; single interambulacrum elevated. Apical system excentric, nearer the anterior border. Peristome small, excentric, nearer the anterior margin. Periproct oval, situated in a narrow sulcus, that terminates above in a projecting arch.

Dimensions.—Characteristic specimen: Length 25 millimeters; width 21.9 millimeters; height 14 millimeters.

Description.—The test of this very beautiful little form is ovate, with rounded, inflated sides and elevated upper surface. The base is nearly flat, slightly concave in the vicinity of the peristome, and lobed posteriorly.

The ambulacra are narrowly lanceolate, subpetaloidal on the upper surface, the posterior areas being much longer than the others. The plates in the petaloid portions are narrow but beyond increase in breadth.

The interambulacral plates are covered with minute tubercles, between which are numerous microscopic granules.

The apical system is small, excentric, and situated far anterior to the apex.

The peristome is small and situated nearer the anterior margin.

The periproct is oval and placed at the upper part of a nearly vertical anal sulcus. The upper margin of this sulcus forms a beak-shaped prominence that overhangs the opening.

Related forms.—*C. oviformis* is separated from *C. pusillus* Clark, by its narrower outline, more inflated sides, and the anterior position of its apical system. In form it is somewhat like *C. columbarius* of Europe, but is distinguished from it by the position of the apical system.

Locality.—Timber Creek, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collection.—Academy of Natural Sciences of Philadelphia (1477).

CATOPYGUS PUSILLUS Clark.

Plate XXIX, figures 3a–d.

Catopygus pusillus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Catopygus pusillus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Catopygus pusillus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 65, 66, Pl. XXVII, figs. 3a–d.
Catopygus pusillus Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, p. 292, Pl. XI, figs. 16–19.

Determinative characters.—Test ovate to subquadrate, rounded anteriorly, subquadrate posteriorly, broader behind than before; upper surface elevated; base concave. Ambulacra narrowly lanceolate, subpetaloidal on the upper surface. Apical system small, nearly central. Peristome small, anteriorly placed. Periproct oval in vertical sulcus beneath overhanging arch.

Dimensions.—Characteristic form: Length 15.6 millimeters; width 14 millimeters; height 9.4 millimeters.

Description.—All the specimens of this species examined by the writer are casts, which are, however, sufficiently well preserved to allow determination of all the more important characters. The test is ovate to subquadrate, occasioned by the slight angularity of the posterior margin. The anterior portion is regularly rounded.

The ambulacra are narrow, the posterior pair only slightly longer than the anterior.

The interambulacra are wide and composed of large plates.

The apical system is small and situated nearly in the center of the upper surface.

The peristome is small and placed forward of the center of the base. The periproct is situated in a nearly vertical sulcus that is overhung at its upper extremity by a projecting arch.

Related forms.—*Catopygus pusillus* is separated from *C. oviformis* by its broader and slightly subquadrate form, its less rounded sides, and nearly central position of its apical system.

Locality.—Wordills, Monmouth County, N. J.

Geologic horizon.—Merchantville clay of Matawan group, Upper Cretaceous.

Collection.—U. S. National Museum (2210).

CATOPYGUS WILLIAMSI Clark.

Plate XXIX, figures 4a–d.

Catopygus williamsi Clark, 1907; in Weller, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 292–293, Pl. XII, figs. 1–4.

Determinative characters.—Test ovate, slightly broader posteriorly; upper surface rounded and somewhat elevated; lower surface concave. Apex posterior to apical system. Ambulacra subpetaloidal. Peristome small, near anterior margin. Periproct small, low down on slightly truncated posterior margin.

Dimensions.—Length 26 millimeters; width 22 millimeters; height 15 millimeters.

Description.—The single specimen of this species is a well-preserved cast that clearly shows all of the more important diagnostic features. The test is ovate, slightly broader posteriorly. The posterior margin is but little truncated, affording a nearly oval outline to the ambitus. The upper surface is somewhat elevated, but it is not a highly inflated form. The lower surface is clearly concave.

The ambulacra are subpetaloidal on the upper surface. The posterolateral ambulacra are somewhat longer than the others.

The apical system is slightly excentric, being situated anterior to the apex.

The peristome is small, pentapetaloidal and situated well anteriorly. The periproct is small, low down on the overhanging, truncated posterior margin.

Related forms.—This species is distinct from either *C. oviformis* or *C. pusillus*. Its posterior margin and the position of its periproct very readily separate it.

Locality.—Bluff east of Atlantic Highlands, N. J.

Geologic horizon.—Navesink marl of Monmouth group, Upper Cretaceous.

Collection.—Johns Hopkins University (T 3010).

Catopygus sp.

Catopygus sp. indet. Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, p. 293.

A poorly preserved specimen of Catopygus presents some points of similarity to *C. pusillus* but apparently differs from it in other features. In its imperfect state of preservation it can not be assigned with certainty to that species. Some of the most important diagnostic characters are lacking.

Locality.—Beers Hill Cut, south of Keyport, N. J.

Geologic horizon.—Tinton sand member of the Redbank sand, Monmouth group, Upper Cretaceous.

Collection.—New Jersey Geological Survey.

Genus CASSIDULUS Lamarck.

Cassidulus florealis (Morton).

Plate XXX, figures 1a–l.

Clypeaster sp. Morton, 1830, Acad. Nat. Sci. Philadelphia Jour., 1st ser. vol. 6, p. 202.
Clypeaster florealis Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 294.
Clypeaster florealis Morton, 1834, Synopsis Organic Remains Cretaceous, p. 76, Pl. III, fig. 12, and Pl. X, fig. 12.
Pygurus florealis Agassiz and Desor, 1847, Catalogue raisonné, p. 141.
Clypeaster florealis Bronn, 1848, Index palæontologicus, p. 312.
Faujasia florealis D'Orbigny, 1853–1860, Paléontologie française, vol. 6, p. 319, Pl. CMXX, figs. 5, 6.
Faujasia florealis Desor, 1858, Synopsis des échinides fossiles, p. 318.
Clypeaster florealis Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 18.
Cassidulus florealis Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 2.
Pygurus florealis Conrad, 1868, Geology of New Jersey, App. A, p. 722.
Cassidulus florealis Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Cassidulus florealis Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Cassidulus florealis Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 66, 67, Pl. XXVIII, figs. 1a–l.
Cassidulus florealis Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.

Determinative characters.—Test subconical in outline, subpentagonal, slightly longer in the anteroposterior diameter than the lateral, rounded anteriorly, angular posteriorly; apex slightly forward of the center. Ambulacra narrow; poriferous zones petaloidal on the upper two-thirds of the dorsal surface. Interambulacra wide, covered with small perforated tubercles. Apical system small, situated anteriorly. Peristome pentagonal, with well developed floscelle. Periproct supramarginal, in a short, narrow sulcus.

Dimensions.—Length 35 millimeters; breadth 32 millimeters; height 19 millimeters.

Description.—This species, the earliest of this genus recognized from American deposits, has a subconical test of moderate height, with a subpentagonal margin. The angularity is more pronounced posteriorly than anteriorly, the anterior portion of the margin being distinctly rounded. The anteroposterior diameter is but slightly greater than the lateral, while the height is a little more than one-half of the same. The apex is a short distance in front of the center of the upper surface, the slope of the anterior face being sharper than that of the posterior.

The ambulacra are narrow. The poriferous zones consist of a double row of pores that are arranged in petaloidal form on the upper two-thirds of the dorsal surface and as phylloidal expansions in the vicinity of the mouth edges. In the petaloidal portion the pores of the inner

row are oval, those of the outer elongated, and each pair united by a shallow furrow. Toward the margin the pores are smaller and placed near together and so continue until near the peristome, where the poriferous zones suddenly expand. At this point the pores increase in size and distance from one another. Between the oral lobes the poriferous zones again suddenly contract.

The interambulacra are of unequal width; the anterior pair are the narrowest; the three posterior are of about equal width and nearly one-half wider than the anterior. The surface of the plates is irregularly covered with numerous small perforated tubercles, with sunken areolas between which are numerous microscopic granules.

The apical system is composed of four perforated genital and five small ocular plates. The fifth genital is obsolete. The large right anterolateral genital plate, the madreporite, extends across the disk, forming a large portion of the center of that body.

The peristome is large, pentagonal, and slightly nearer the anterior margin. It is surrounded by five prominent lobes that project over the oral opening. The ambulacra are contracted between the lobes and expand beyond them into wide phylloidal areas, producing a peculiar, somewhat star shaped form that has been termed the floscelle.

The periproct is small, circular, and supramarginal, and is situated in a short, narrow sulcus.

Related forms.—*Cassidulus floralis* is allied to *C. æquoreus*, although the latter is more depressed and more elongated. In some points it is similar to *C. subconicus* but has a less sharply defined pentagonal outline, a differently situated periproct, and less elongated pores in the outer rows of the petaloidal areas.

Localities.—Chesapeake & Delaware Canal, Del. (type); Uniontown, Ala.

Geologic horizon.—Matawan formation, Delaware, and Selma chalk, Alabama, of the Upper Cretaceous.

Collection.—Academy of Natural Sciences of Philadelphia (1495).

Cassidulus æquoreus Morton.

Plate XXX, figures 2a–i.

Cassidulus æquoreus Morton, 1834, Synopsis Organic Remains Cretaceous, p. 76, Pl. III, fig. 14.
Cassidulus æquoreus Desmoulins, 1837, Études sur les échinides, p. 146.
Cassidulus æquoreus Lamarck, 1840, Hist. Nat., vol. 3, p. 341.
Cassidulus æquoreus Agssiz and Desor, 1847, Catalogue raisonné, p. 141.
Cassidulus æquoreus D'Orbigny, 1847, Prodrome, vol. 2, p. 271.
Cassidulus æquoreus Bronn, 1848, Index palæontologicus, vol. 1, p. 244.
Cassidulus æquoreus D'Orbigny, 1853–60, Paléontologie française, vol. 6, p. 329, Pl. CMXXVI, figs. 6–12.
Cassidulus æquoreus Desor, 1858, Synopsis des échinides fossiles, p. 290.
Cassidulus æquoreum Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 13.
Cassidulus æquoreus Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 2.
Cassidulus æquoreus Conrad, 1868, Geology of New Jersey, App. A, p. 722.
Cassidulus æquoreus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Cassidulus æquoreus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Cassidulus æquoreus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 68, 69, Pl. XXIX, figs. 1a–i.
Cassidulus æquoreus Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.
Cassidulus æquoreus Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 293–294, Pl. XII, figs. 5–12.

Determinative characters.—Test subpentagonal, depressed; upper surface convex; under surface concave, slightly rostrated posteriorly; apex forward of the center. Ambulacra narrow; poriferous zones petaloidal on the upper surface; contracted above the margin and expanded again on the lower surface, much narrowed at the peristome. Interambulacra wide, covered with small perforated tubercles. Apical system small, situated forward of the center. Peristome small, with floscelle. Periproct supramarginal, in short sulcus.

Dimensions.—Typical form: Length 31.25 millimeters; width 28.12 millimeters; height 15.6 millimeters.

Description.—This typical Cassidulus, early recognized as such by Morton, has a depressed test, subpentagonal in outline. It is longer in the anteroposterior diameter than the lateral. The upper surface is convex, with sharp marginal edges, while the lower surface is flat, with a slight concavity toward the center. The apex is somewhat anterior to the center.

The ambulacra are narrow. The poriferous zones are uniserial, the pores of the upper part of the aboral surface arranged in petaloidal form. At a point varying in the different areas from one-quarter to one-third of the distance from the margin to the apical system the zones are contracted and continue as narrow bands over the margin and to the vicinity of the peristome, where they broaden again perceptibly, becoming finally much contracted at the margin of the oral opening. The pores are distinct in the petaloidal portion and in the broadened area near the peristome but in the intermediate contracted portion are small and indistinct. The interambulacra are broad and covered by small perforated tubercles with sunken areolas.

The apical system is composed of four perforated genital and five small ocular plates. As explained under the previous species, the fifth genital is obsolete.

The peristome is pentagonal and surrounded by a well-developed floscelle. The oral lobes are very prominent and the ambulacral furrows much contracted.

The periproct is situated in a short sulcus on the upper surface.

Related forms.—This species is separated from *C. florealis* by its more depressed and elongated form. From *C. micrococcus* it is separated by its sharper apex, more angular margin, the position of its periproct, and the shorter pore openings in its outer rows.

Localities.—Prairie Bluff, Ala. (type); bluff east of Atlantic Highlands, N. J.

Geologic horizon.—Navesink marl of Monmouth group, New Jersey, and Ripley formation, Alabama; Upper Cretaceous.

Collection.—Academy of Natural Sciences of Philadelphia (1475).

Cassidulus micrococcus Gabb.

Plate XXXI, figures 1a–i.

Cassidulus micrococcus Gabb, 1860, Acad. Nat. Sci. Philadelphia Proc., p. 519.
Cassidulus micrococcus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Cassidulus micrococcus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Cassidulus micrococcus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 69, 70, Pl. XXX, figs. 1a–i.
Cassidulus micrococcus Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.

Determinative characters.—Test oval, rounded anteriorly, slightly rostrated posteriorly; upper surface convex, flattened at the apex; sides equally declining. Ambulacra moderately broad; poriferous cones petaloidal on dorsal surface; outer row of pores slitlike in petaloidal portion. Peristome small, pentagonal, with floscelle. Periproct oval, situated high on upper surface, in long, narrow sulcus.

Dimensions.—Length 45 millimeters; width 42 millimeters; height 21.5 millimeters.

Description.—This species has a distinctly oval form, wider posteriorly. The upper surface is elevated at the margin but somewhat flattened at the apex. The sides decline very nearly equally. The base is flattened, with a slight concavity at the peristome. The posterior margin is truncated and slightly rostrated.

The ambulacra are rather broad, contracted about one-quarter of the distance from the ambitus to the apex, and narrowed nearly to the peristome, where they are again broadened to form indistinct phylloidal areas. The pores are slitlike in the outer rows of the petaloidal portion.

The interambulacral plates are covered with minute tubercles, with sunken areolas, that increase in size and number of the oral surface.

The apical system is situated slightly in front of the upper surface, in a long, narrow, and deep sulcus.

Related forms.—A comparison of this species with *Cassidulus æquoreus*, as made also by Gabb in his original description, shows that it is much larger and more oval, and that its periproct is situated higher and in a deeper and longer sulcus, and, furthermore, that the pores of the outer row in its petaloidal portion are elongated and slitlike.

Locality.—Eufaula, Ala.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—Academy of Natural Sciences of Philadelphia (1480).

Cassidulus subquadratus Conrad.

Plate XXXI, figures 2a–g.

Cassidulus subquadratus Conrad, 1860, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 4, p. 291, Pl. XLVII, fig. 19.
Cassidulus subquadratus A. Agassiz, 1883, Mus. Comp. Zool. Mem., vol. 10, p. 90.
Cassidulus subquadratus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Cassidulus subquadratus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Cassidulus subquadratus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 70, 71, Pl. XXXI, figs. 1a–h.
Cassidulus subquadratus Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.
Cassidulus subquadratus Slocum, 1909, Field Mus. Nat. Hist. Pub. 134, Geol. ser., vol. 4, No. 1, pp. 5, 6.

Determinative characters.—Test subquadrate to subpentagonal, hemispherical; sides equally declining, upper surface convex; lower surface concave; posterior margin truncated and rostrated. Poriferous zones broadly petaloidal on upper two-thirds of the dorsal surface; sharply contracted at lower margin of petaloidal areas. Peristome small, pentagonal, with well-defined floscelle. Apical system large, slightly anterior to the center. Periproct round, in deep sulcus.

Dimensions.—Length 56.5 millimeters; width .53 millimeters, height 28 millimeters.

Description.—This remarkably symmetrical Cassidulus has a nearly hemispherical form. In outline it is nearer subpentagonal than subquadrate, owing to the rostrated character of the posterior margin, which is at the same time truncated. The anterior margin is rounded. The lateral edges are nearly parallel, though somewhat more approximated anteriorly. The apex is slightly forward of the center.

The ambulacra are moderately wide in the petaloidal portion, narrow beyond. The poriferous zones are composed in the petaloidal portion of an inner row of small, nearly circular pores and of an outer row of oblique slitlike openings. The pores of each pair are united by a shallow furrow. Beyond the petaloidal areas the narrow plates of those portions give place to broad plates, each with a pair of small, round pores in the lower and outer corner. In the vicinity of the peristome the poriferous zones expand and the pores increase in size, though apparently reduced in number. The last pair of plates are much contracted.

The interambulacra are wide. The plates are covered with minute tubercles with depressed areolas, which become larger and more prominent on the lower surface.

The apical system is large, composed of four perforated genital and five ocular plates. The fifth genital is apparently obsolete.

The peristome is small, pentagonal, and surrounded by a well-developed floscelle. The periproct is round and is situated high above the margin, in a deep sulcus, that becomes narrower and shallower toward the ambitus.

Related forms.—This species is most closely related to *Cassidulus subconicus*, but the latter is much more elevated and has its periproct situated higher and in a less depressed sulcus.

Locality.—Near Holly Springs, Miss.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—U. S. National Museum (31200).

Cassidulus subconicus Clark.

Plate XXXII, figures 1a–k.

Cassidulus subconicus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Cassidulus subconicus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Cassidulus subconicus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 71, 72, Pl. XXXII, figs. 1a–k.

Determinative characters.—Test subconical; margin subpentagonal, truncated and rostrated posteriorly; apex anteriorly placed. Ambulacra broad in petaloidal areas. Apical system large, anteriorly situated. Peristome subcircular, with very prominent floscelle. Periproct large, situated high on upper surface, in shallow sulcus.

Dimensions.—Length 47 millimeters; width 43 millimeters; height 27.5 millimeters.

Description.—The test is subconical. In marginal outline it is subpentagonal, the posterior border more or less rostrated and clearly truncated. The apex is slightly forward of the center, giving a somewhat sharper slope to the anterior portion of the test than to the posterior.

The ambulacra are broad in the petaloidal portion, beyond which they are narrowed. At the margin they again acquire considerable width but gradually contract beyond, although expanded for a short distance in the phylloidal area near the peristome. At the peristome the final pair of plates is highly attenuated. The pores of the outer rows, in both the petaloidal and phyloidal areas, are in a marked degree elongated. In the intermediate portion of the column they are small and indistinct.

The interambulacra are more prominent than the ambulacra, which are slightly depressed. The surface is covered with minute tubercles and a microscopic granulation.

The apical system is large, subcircular, and surrounded by a very prominent floscelle. The periproct is large, circular, and is situated high above the margin in a shallow sulcus.

Related forms.—*C. subconicus* is closely related to *C. subquadratus* but is separated from it by its high subconical test, more elevated periproct, and shallow anal sulcus.

Locality.—Dumas, Miss.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—U. S. National Museum (20264).

Cassidulus porrectus Clark.

Plate XXXII, figures 2a–b; Plate XXXIII, figures 1a–f.

Cassidulus porrectus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Cassidulus porrectus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Cassidulus porrectus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 72, 73, Pl. XXXIII, figs. 1a–b, Pl. XXXIV, figs. 1a–b., Pl. XXXV, figs. 1a–d.

Determinative characters.—Test very large, subcircular, oval, depressed; upper surface convex; lower surface concave; broader posteriorly than anteriorly; apex forward of the center. Ambulacra broad. Interambulacra thickly covered with minute tubercles. Apical system small, forward of the center. Peristome large, subconical, with prominent floscelle. Periproct supramarginal, in short shallow sulcus.

Dimensions.—Length 99.6 millimeters; width 97.5 millimeters; height 44.5 millimeters.

Description.—This very large Cassidulus has an irregularly oval, depressed test, that is subcircular in marginal outline. The width is equal to the length but is greatest in the posterior portion, so that the margin appears contracted anteriorly. The apex is some distance forward of the center and slightly flattened. The posterior margin is feebly truncated.

The ambulacra are wide; the contractions below the petaloidal region and above the phylloidal continue for short distances, while the lowest pair of plates in the column bordering the peristome are long and greatly attenuated. The pores of the outer rows are slitlike in form and obliquely placed.

The interambulacra are prominent; the plates are covered with numerous small tubercles, with depressed areolas, which are larger and more prominent on the under than the upper surface. The apical system is small and is placed forward of the center.

The peristome is large, subcircular, with very prominent floscelle. The oral lobes project far beyond the level of the base and are separated by deep ambulacral furrows.

The periproct is large, oval, and is situated at the head of a short, narrow sulcus.

Related forms.—*C. porrectus* is from its size, form, and details of structure readily separated from the other species of Cassidulus described from the American and European Cretaceous.

Locality.—Eufaula, Ala.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—U. S. National Museum (21890).

Cassidulus stantoni Clark.

Plate XXXIII, figures 2a–d.

Cassidulus stantoni Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
Cassidulus stantoni Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Cassidulus stantoni Clark, 1893, U. S. Geol. Survey Bull. 97, p. 73, Pl. XXXV, figs. 2a–d.

Determinative characters.—Test small, subovate, elevated; upper surface convex, lower surface concave; apex forward of the center. Ambulacra very narrow. Apical system small, forward of the center. Peristome small, with floscelle. Periproct high above margin, in long, narrow, and deep sulcus.

Dimensions.—Length 15 millimeters; width 14 millimeters; height 6.5 millimeters.

Description.—This minute Cassidulus has a subovate test, an elevated convex upper surface, and a concave lower surface. It is broader posteriorly than anteriorly, and its posterior margin is truncated. The apex is situated slightly anterior to the center of the upper surface.

The ambulacra are very narrow. The petaloidal portion but slightly exceeds the remainder in width, which is nearly equal throughout. The phylloidal region is feebly outlined.

The interambulacra are broad, but the poor state of preservation of the specimens renders it impossible to determine all the details of structure.

The apical system is small and forward of the center, but not sufficiently well preserved to distinguish the individual plates. The peristome is small and surrounded by a feeble floscelle. The periproct is round and situated high above the margin, at the head of a narrow deep sulcus.

Related forms.—*C. stantoni* is quite unlike any other representative of this genus from American strata and can not be readily associated with any European species.

Locality.—Muddy Creek, Huerfano County, Colo.

Geologic horizon.—Colorado group, Upper Cretaceous.

Collection.—U. S. National Museum (20260).

Cassidulus intermedius Slocum.

Plate XXXIV, figures 1a–f.

Cassidulus intermedius Slocum, 1909, Field Mus. Nat. Hist. Pub. 134, Geol. ser., vol. 4, No. 1, pp. 6, 7, Pl. I, figs. 1–6.

Determinative characters.—Test oval, depressed, rounded anteriorly, slightly rostrated posteriorly. Apex excentric anteriorly. Ambulacra narrow. Peristome large, slightly in front of center of ventral surface. Periproct on upper surface, about one-third of the distance from the apex to the margin, in broad deep sulcus.

Dimensions.—Type specimen: Length 25.6 millimeters; width 22.7 millimeters; height 9.6 millimeters.

Slocum says:

Description.—Test oval, greatest width posterior to the center; rounded anteriorly, slightly rostrated posteriorly; dorsal surface convex, apex excentric anteriorly and inflated, sides declining about equally towards the margins which are slightly inflated; the peristomal concavity occupying more than half of the central surface. Ambulacral areas narrow and flush, poriferous zones subpetaloidal on the upper part of the dorsal surface to a point varying in the different areas from about one-third to nearly one-half the distance from the margin to the apical system; the zones are then contracted and continue as narrow bands over the margin to the vicinity of the peristome, where they abruptly widen, and gain narrow to the peristome forming a floscelle. The pores are distant and paired on the petaloid portion and in the floscelle on the narrow connecting portions they are single small and indistinct. In the petaloid areas the pores of the outer rows are slitlike, those of the inner row round and smaller; each pair is connected by a groove. Interambulacral areas composed of large plates, the plates nearest the peristome in each area inflated forming the bourrelets. Dorsal surface covered with small crowded tubercles with slightly sunken areoles, the tubercles on the ventral surface rapidly increasing in size and distance apart as they approach the peristome. A wide, longitudinal median band extends from near the anterior margin through the floscelle to the posterior margin. This band is without tubercles and the surface is smooth except where it passes through the floscelle. The apical system in the type specimen is too incomplete for detailed description, but appears similar to other species of this genus. The peristome is situated slightly in front of the center of the ventral surface, pentagonal, surrounded by a well-marked floscelle, the bourrelets large and prominent

the phyllodes very narrow as they reach the peristome and situated in grooves. The periproct is elongated longitudinally and situated on the dorsal surface about one-third the distance from the posterior margin to the apex in a deep groove.

Related forms.—In general form this species resembles *C. æquoreus*, but is not so high in proportion to its length, the periproct is somewhat higher, the pores in the outer rows of the petaloid portions are slitlike instead of round, and the expansions of the phyllodes are wider. *C. intermedius* resembles *C. micrococcus* in the slitlike pores of the outer rows of the petaloid areas and in the expansion of the phyllodes, but the position of the pores in these expansions is more like those of *C. æquoreus*. The position of the periproct is midway between that of *C. micrococcus* and *C. æquoreus*, the size and shape of the test is quite unlike *C. micrococcus* and the extension of the longitudinal median band in front of the peristome on the ventral surface does not appear, from the description and figures, to occur in either of the other species. The name adopted for this species refers to the characters intermediate between *C. æquoreus* and *C. micrococcus* which the species exhibits.

Locality.—Near the southern edge of the village of Pontotoc (Slocum), Miss.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—Field Museum of Natural History (P 10346).

Cassidulus hemisphericus Slocum.

Plate XXXIV, figures 2a–c.

Cassidulus hemisphericus Slocum, 1909, Field Mus. Nat. Hist. Pub. 134, Geol. ser., vol. 4, No. 1, pp. 7, 8, Pl. I, figs. 7–9.

Determinative characters.—Test subhemispherical, elevated, margins angular, lower surface flat. Ambulacra wide. Peristome nearly central. Periproct supramarginal.

Dimensions.—Type specimen: Length 34.7 millimeters; width 26.7 millimeters; height 19.5 millimeters. Allowing for the lateral crushing it is probable that the length and width were originally about 32 millimeters and 29 millimeters, respectively.

Description.—Slocum says:

Test subhemispherical with its transverse diameter somewhat shorter than the longitudinal, sides arcuate, margins angular, ventral surface flat or nearly so. Ambulacral areas wide, subpetaloidal on the top of the dorsal surface, not closed distally, petals subequal in length, extending about halfway from the apex to the margin, slightly convex; from the distal end of the petals the ambulacral areas are continued as a band which gradually increased in width from the petal to the margin, most of the way being wider than the petal. On the ventral surface the bands slightly narrow to the floscelle. The floscelle is not well preserved in the type specimen, but enough is preserved to determine that the bourrelets are prominent and that the phyllodes are in grooves. The apical system is central but the form of the various plates of which it is composed can not be determined. The interambulacral areas are about equal in size. They form an acute angle near the apex and rapidly expand to the margin, the plates being comparatively large. All the plates of the dorsal surface, with the exception of those of the petals, are marked by prominent lines subparallel to the edge of the plates. These lines are farther apart on the lateral edges than on the proximal and distal edges. They appear to be lines of growth. The middle portion of the plates within this series of lines is inflated, so that in the small plates of the interambulacral areas, near the apex, the centers of the plates appear as prominent nodes. These middle portions of the plates are free from tubercles, but the parts of the plates covered by the parallel lines and the plates of the petals are covered with minute tubercles closely crowded together. The lines are much less prominent on the plates of the ventral surface and the tubercles are larger, with slightly sunken areoles, and more evenly distributed over the surface, except on the longitudinal median band, which extends from the peristome to the posterior margin. The peristome is situated at the center of the ventral surface, surrounded by a floscelle, the bourrelets are prominent, and the phyllodes are depressed and contracted into narrow grooves where they reach the peristome. The periproct is supramarginal, but its form and exact position are unknown, because that portion of the posterior interambulacral area near the margin is missing.

Locality.—The "white gullies" on the Patterson farm, about 3 miles south of Pontotoc, Miss.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—Field Museum of Natural History (P 10347).

Cassidulus conoideus Clark, n. sp.

Plate XXVII, figures 3a–d.

Determinative characters.—Test moderate, nearly circular, inflated above, flat below. Apical system excentric anteriorly. Ambulacra nearly similar, subpetaloid. Peristome excentric forward. Periproct supramarginal in poorly defined groove.

Dimensions.—Length 31.5 millimeters; width 32 millimeters; height 28 millimeters.

Description.—This species has a test of moderate size, nearly circular and much elevated. The apex is near the center of the upper surface. The upper surface is convex, the lower nearly flat.

The ambulacra are wide, nearly similar, distinctly petaloidal above. The interambulacra are prominent, projecting slightly above the ambulacra.

The peristome is of small size and excentric forward. The periproct is small, supramarginal and located in a very poorly defined groove. The material of the test has been destroyed, only a cast remaining.

Locality.—Pataula Creek, Clay County, Ga.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—U. S. National Museum (31199).

Cassidulus abruptus Conrad.

Cassidulus abruptus Conrad, 1860, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 4, p. 291.
Cassidulus abruptus Agassiz, 1883, Mus. Comp. Zoology Mem., vol. 10, No. 1, p. 90.
(?) *Cassidulus abruptus* Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
(?) *Cassidulus abruptus* Clark, 1893, U. S. Geol. Survey Bull. 97, p. 92.

This species, originally described by Conrad in 1860, but not figured, has not been recognized in material examined by the writer, so that its relations to the other forms described are not known.

Locality.—Tippah County, Miss.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—Unknown.

?Cassidulus subangulatus (Emmons).

Gonioclypeus subangulatus Emmons, 1858, North Carolina Geol. Survey Rept., p. 309, figs. 242, 243.
Gonioclypeus subangulatus Conrad, 1866, Check list, p. 31.

This species, which is described from the "Eocene, Wadsworth marl, Craven County," N. C., by Emmons is probably a Cretaceous form and if the strata in which it was found are Eocene was doubtless mechanically transported from older deposits. It is apparently identical with *C. subquadratus* Conrad, but as its type form is unknown and no further material has been found it seems wiser to maintain the separation of the two species until more positive data are secured.

Locality.—Craven County, N. C.

Geologic horizon.—Peedee sand (?), Upper Cretaceous.

Collection.—Unknown.

Suborder STERNATA.

Family ECHINOCORYTHIDÆ.

Genus ANANCHYTES Mercati.

Ananchytes ovalis Clark.

Plate XXXV, figures 1a–h.

Ananchytes ovalis Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Ananchytes ovalis Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 74, 75, Pl. XXXVI, figs. 1a–h.
Ananchytes ovalis Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, p. 295, Pl. XIII, figs. 1–8.

Determinative characters.—Test medium sized, subovate cordate; contracted posteriorly; upper surface convex; lower surface flat. Apical system elongated, consisting of four perforated genital and five ocular plates situated slightly forward of the center. Peristome near the anterior margin. Periproct oval, situated on a slight protuberance of the posterior margin.

Dimensions.—Length 43.75 millimeters; width 37.5 millimeters; height 31.25 millimeters.

Description.—The specimens of this species collected by the writer are remarkably well preserved and admit of the determination of all the essential features. The test is in lateral outline subovate, though somewhat cordate in form when viewed from above or below. A marked protuberance is present on the posterior margin that appears as a slight ridge on the lower surface between the peristome and periproct. The upper surface is convex. The sides are full and rounded at the ambitus. The base is nearly flat, with the exception of the slight ridge and depressed peristome.

The ambulacra are wide and straight, attaining their greatest width just above the ambitus. The pores are oval, and those of each pair are placed toward the ambitus at an angle to one another. The surface of both the ambulacral and interambulacral plates is covered by small tubercles, between which are numerous microscopic granules. The apical system is elongated. The four genital plates are large and distinctly perforated. The anterior, right-hand genital plate, which serves as the madreporite, is much larger than any of the others, being several times the size of the anterior left-hand genital, with which it is in contact. The posterior genitals are very nearly of equal size.

The peristome is transversely oblong and situated near the anterior margin. The periproct is oval and situated on a marked protuberance on the posterior margin.

Locality.—Vincentown, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collection.—Johns Hopkins University (T 3011).

Ananchytes texana Cragin.

Plate XXXV, figures 2a–c; Plate XXXVI, figures 1a–b.

Ananchytes texana Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., pp. 145, 146, Pl. XXVI, figs. 1, 2, Pl. XXV, fig. 12.

Determinative characters.—Test large, high, oval in marginal outline, rounded anteriorly, narrowed posteriorly; upper surface convex, lower surface flat; ambulacra flush, nearly alike, apetalous pair of pores more strongly developed on upper surface; interambulacra with large plates covered with few primary tubercles and many granules; peristome far in front; periproct well forward on lower surface.

Dimensions.—Length 107 millimeters; width 87 millimeters; height 68 millimeters.

Description.—Cragin says:

> Large conico-hemispherical as seen from the side; plan ovate, wider anteriorly; peristome of moderate size, transverse, oblong-reniform, the anterior lip and immediately contiguous surface deeply and abruptly depressed, the remainder of the interior surface slightly depressed, the depression being posteriorly parted by a gentle median undulation that includes the periproct and becomes gradually obsolete a short distance in advance of it; periproct inframarginal and relatively smaller than in most (if not all) other known species of the genus, rather narrowly ovate and posteriorly more or less pointed; anterior ambulacrum about two-thirds as wide as either of the adjacent interambulacra, ambulacral plates very numerous and narrow, averaging about a millimeter in width on the greater part of the zone; the pores rounded but usually more or less transversely elongated, the line connecting the pores of one pair being horizontal except in the case of a few of the lower pairs; surface nearly even, the principal tubercles rather small and not very prominent.

Locality.—Two and one-half miles northwest of D'Haniss, on Seco Creek, Medina County, Tex. (type); White Cliffs, Ark.

Geologic horizon.—Austin chalk and Annona chalk, Upper Cretaceous.

Collections.—Geological Survey of Texas; Johns Hopkins University.

Genus CARDIASTER Forbes.

Cardiaster cinctus (Morton).

Plate XXXVI, figures 2a–h.

Spatangus sp. Morton, 1829, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, p. 122.
Ananchytes sp. Morton, 1830, Am. Jour. Sci., 1st ser., vol. 17, p. 287.
Ananchytes cinctus Morton, 1830, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, p. 200.
Ananchytes fimbriatus Morton, 1830, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, p. 200.
Ananchytes cinctus Morton, 1830, Am. Jour. Sci., 1st ser., vol. 18, p. 246, Pl. III, fig. 7.
Ananchytes fimbriatus Morton, 1830, Am. Jour. Sci., 1st ser., vol. 18, p. 245, Pl. III, fig. 9.
Ananchytes cinctus Morton, 1834, Synopsis Organic Remains Cretaceous, p. 78, Pl. III, fig. 19.
Ananchytes fimbriatus Morton, 1834, Synopsis Organic Remains Cretaceous, pp. 77, 79, Pl. III, fig. 20.
Holaster cinctus Agassiz and Desor, 1840, Catalogue systématique, p. 1.
Holaster cinctus Agassiz and Desor, 1847, Catalogue raisonné, p. 133.
Holaster fimbriatus Agassiz, 1847, Catalogue raisonné, p. 141.
Holaster cinctus D'Orbigny, 1847, Prodrome, vol. 2, p. 269.
Holaster fimbriatus D'Orbigny, 1847, Prodrome, vol. 2, p. 269.
Holaster cinctus Bronn, 1848, Index palæontologicus, vol. 1, p. 593.
Ananchytes fimbriatus Bronn, 1848, Index palæontologicus, vol. 1, p. 70.
Cardiaster cinctus Bronn, 1853–1856, Lethæa geognostica, vol. 2, pt. 5, p. 205.
Cardiaster cinctus D'Orbigny, 1853–1860, Paléontologie française, vol. 6, p. 147; Pl. CMXCV, fig. 4.
Cardiaster fimbriatus D'Orbigny, 1853–1860, Paléontologie française, vol. 6, p. 147; Pl. CMXCV, fig. 3.
Cardiaster cinctus (*Cardiaster fimbriatus*) Desor, 1858, Synopsis des échinides fossiles, p. 346.
Ananchytes cinctus Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 18.
Ananchytes fimbriatus Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 18.
Holaster cinctus Credner, 1870, Deutsche geol. Gesell. Zeitschr., vol. 22, p. 218.
Holaster cinctus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Cardiaster cinctus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Cardiaster cinctus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 75, 76, Pl. XXXVII, figs. 1a–h.
Cardiaster fimbriatus Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.
Cardiaster cinctus Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.
Cardiaster cinctus Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 296–297, Pl. XVI, figs. 1–8.

Determinative characters.—Test large, cordate, distinctly grooved anteriorly; contracted posteriorly; upper surface convex; lower surface flat. Ambulacra wide. Apical system much elongated, consisting of four perforated genital and five ocular plates situated slightly forward of the center. Peristome near the anterior margin. Periproct oval, situated on the truncated posterior margin.

Dimensions.—Length 30 to 60 millimeters; width 25 to 55 millimeters; height 20 to 30 millimeters.

Description.—This species, which is among the earliest of the Echinoid forms recognized from American Cretaceous strata, is distinctly cordiform, with a pronounced groove on the anterior face that is occupied by the unpaired ambulacrum. Opposite thereto is a slight ridge at the central suture of the unpaired posterior interambulacrum which is suddenly terminated by the nearly vertically truncated surface of the posterior margin. The sides decline equally to the ambitus, giving an oval outline to the vertical lateral section. The lower surface is nearly flat, with the exception of the slight depressions directly at the mouth edges and the elevated area extending from the center of the base to the posterior margin.

The ambulacra are wide, petaloid, and separated at the apex. The anterolateral pair are bent backward in their upper part, beyond which they extend straight to the margin. The postero-lateral pair are bent somewhat forward, after which they extend straight over the margin. The single ambulacrum is situated in the deep anterior sulcus. The pores of the paired ambulacra consist, in the upper portion of the columns, of oblique oval openings united by furrows while lower down they become small and often indistinct. In the unpaired ambulacrum the pores are extremely small.

The surface of the interambulacral as well as of the ambulacral plates is covered with fine granules, among which are irregularly scattered numerous small perforated tubercles.

The apical system is narrow, elongated. The four perforated genital plates are disposed in pairs, between which two of the five ocular plates are situated. Forming the posterior portion of the disk are two more ocular plates, while the fifth plate comprises the anterior part. The ambulacral areas are on this account separated at their apices.

The peristome is transversely oblong and is situated near the anterior margin of the base. The periproct is oval and situated on the truncated surface at the posterior margin of the test.

Localities.—Vincentown and Timber Creek, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collections.—Academy of Natural Sciences of Philadelphia (1485); American Museum of Natural History, New York.

Cardiaster smocki Clark.

Plate XXXVI, figures 3a–c.

Cardiaster smocki Clark, 1907; Weller, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, p. 298, Pl. XIII, figs. 9–11.

Determinative characters.—Test cordiform, elevated, with deep anterior sulcus; upper surface convex; lower surface flat. Ambulacra wide. Apical system elongated. Peristome near the anterior margin.

Dimensions.—Length 25 millimeters; width 23 millimeters; height 14 millimeters.

Description.—The test is small, distinctly elevated, with strongly convex upper surface. The anterior ambulacral sulcus is very pronounced, and the opposite ridge in the unpaired posterior interambulacrum is well shown but is sharply cut off by the nearly vertically truncated surface of the posterior margin. The sides slope rapidly to the ambitus, which is sharp and cordate in outline. The lower surface is nearly flat.

The ambulacra are wide, apetaloid, and well separated at the apex. The anterolateral pair are bent backward above, beyond which they extend straight to the ambitus. The postero-lateral pair are bent slightly forward, beyond which they continue in a straight line over the margin. The unpaired ambulacrum is situated in the deep anterior sulcus.

The apical system is much elongated, widely separating the ambulacral areas.

The peristome is situated anteriorly and is transversely oval.

Related forms.—This species is most closely related to *Cardiaster cinctus* but is smaller and has a somewhat less pronounced anterior sulcus and a more inflated test.

Locality.—Two and a half miles northwest of Matawan, N. J.

Geologic horizon.—Merchantville clay of Matawan group, Upper Cretaceous.

Collection.—Geological Survey of New Jersey.

Cardiaster curtus Clark, n. sp.

Plate XXXVII, figures 1a–h.

Determinative characters.—Test small, cordate, high anteriorly, clearly marked anterior groove with well-defined keel on either side; ambulacra wide, interambulacra with large plates; peristome near posterior margin.

Dimensions.—Length 22 millimeters; width 19 millimeters; height 12 millimeters.

Description.—The two specimens of this small species are fragmentary although retaining the most important characteristic portions.

The test is cordate, elevated toward the posterior margin and with broad and deep anterior groove. The ambulacra are broad, the poriferous zones are clearly marked on the upper surface. The pore pairs are oval above and more nearly round toward the ambitus. The surface of the plates is covered by minute granules.

The interambulacra are composed of large plates covered with minute granules.

The apical system is elongate, the four genitals varying in shape and size. The two antero-lateral oculars are very large and separate the antero-lateral from the postero-lateral genitals which are in contact, the latter isolating the two postero-lateral oculars from the remainder of the apical system.

The peristome is near the posterior margin. The periproct is not preserved.
Locality.—Twenty-five miles southwest of Mingusville (now Wibaux), Mont.
Geologic horizon.—Fox Hills (?) sandstone of Montana group, Upper Cretaceous.
Collection.—U. S. National Museum (31201).

Genus HOLASTER Agassiz.

Holaster simplex Shumard.

Plate XXXIV, figures 3a–b; Plate XXXVIII, figures 1a–j; Plate XXXIX, figures 1a–g.

Holaster simplex Shumard, 1853, Pal. Expl. Red River of Louisiana in 1852, p. 210, Pl. III, fig. 2.
Holaster comanchesi Marcou, 1858, Geology of North America, p. 40, Pl. III, fig. 3
Holaster simplex Desor, 1858, Synopsis des échinides fossiles, p. 450.
Holaster comanchesi Desor, 1858, Synopsis des échinides fossiles, p. 449.
Holaster simplex Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Holaster comanchesi Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Holaster simplex Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 3.
Holaster comanchesi Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 3.
Holaster simplex Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Holaster simplex Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Holaster simplex Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 76–78, Pls. XXVIII, figs. 1a–g; Pl. XXXIX, figs. 1a–d.
Holaster completus Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., pp. 155, 156, Pl. XXIV, fig. 10; Pl. XXV, fig. 14; Pl. XXVI, figs. 6–8.
Holaster nanus Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 156, Pl. XXIV, fig. 14; Pl. XXVI, fig. 11.
Holaster simplex Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 157, Pl. XXV, fig. 13.
Holaster supernus Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., pp. 157, 158.
Holaster completus Cragin, 1894, Colorado Coll. Studies, vol. 5, pp. 45, 47.
Holaster nanus Cragin, 1894, Colorado Coll. Studies, vol. 5, pp. 45, 47.

Determinative characters.—Test oblong, cordiform; upper surface much elevated, rounded, and grooved on the anterior face; lower surface flat; apex nearly central. Ambulacra wide; pores unigeminal, with slitlike openings in the upper portion of the column that become indistinct toward the margin and upon the base. Apical system compact and not greatly elongated. Peristome transversely oval, situated near the anterior margin. Periproct large, on truncated posterior margin.

Dimensions.—Length 32 to 70 millimeters; width 30 to 60 millimeters; height 14 to 53 millimeters.

Description.—The test is oblong, cordiform, much elevated, rounded above and flattened below. A shallow groove occupies the anterior face of the test, producing a feeble emargination of the anterior ambitus. A slight ridge extends along the line of the central suture of the single interambulacrum, which is suddenly terminated by the truncated face of the posterior margin.

The ambulacra are wide. The poriferous zones of the paired ambulacra are in the case of the posterior pair bent more or less forward in their upper portions, and in the case of the anterior slightly backward. The pores of the paired ambulacra have elongated openings in the upper portion and become very small and indistinct below. The pores of the unpaired ambulacrum are exceedingly small.

The surface of both interambulacral and ambulacral plates are covered by small tubercles, between which are numerous microscopic granules.

The apical system is compact and rather short. The four genital plates are large and broad. The two interposed oculars are large, the remaining three very small.

The peristome is large, transversely oblong, and situated near the anterior margin. The periproct is oval, acuminate above, and situated on the truncated posterior border.

The variations in this species are very pronounced, some of the individuals being high and globose and others low and flat. A critical examination of a large number of specimens affords no satisfactory criteria for the recognition of the new species established by Marcou and Cragin.

Related forms. *H. simplex* is very like *H. laevis* var. *planus*, from the European Cretaceous, but is more elevated and distinctly broader posteriorly.

Localities.—Fort Washita (type), Bexar County (figured specimen A), near Fort Worth, at Preston, Grayson County (figured specimen B), on the Red River, near Austin, and near El Paso, Tex.; near Fort Washita, Okla.

Geologic horizon.—Washita group of the Comanche series, Cretaceous.

Collections.—U. S. National Museum (8382A); Geological Survey of Texas (B); Johns Hopkins University.

Family SPATANGIDÆ.

Genus ENALLASTER D'Orbigny.

Enallaster texanus (Roemer).

Plate XXXIX, figures 2a–g.

Toxaster texanus Roemer, 1849, Texas, p. 393.
Toxaster texanus Roemer, 1852, Die Kreidebildungen von Texas, pp. 85, 86, Pl. X, fig. 3.
Toxaster ungula Giebel, 1853, Naturwiss. Ver. in Halle Jahresb., p. 373.
Enallaster texanus D'Orbigny, 1853–60, Paléontologie française, vol. 6, p. 184, Pl. DCCCL, figs. 1–7.
Toxaster texanus Conrad, 1857, U. S. and Mex. Boundary Survey Rept., vol. 1, pt. 2, p. 145, Pl. I, figs. 2a–c.
Enallaster texanus Desor, 1858, Synopsis des échinides fossiles, p. 358.
Toxaster texanus Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Toxaster texanus Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 3.
Enallaster texanus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Enallaster texanus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Enallaster texanus Clark, U. S. Geol. Survey Bull. 97, pp. 78, 79, Pl. XXXIX, figs. 2a–g.
Enallaster inflatus Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., pp. 150, 151, Pl. XXIV, fig. 13.
Enallaster texanus Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 151.
Enallaster texanus Cragin, 1894, Colorado Coll. Studies, vol. 5, p. 41.
Enallaster inflatus Cragin, 1894, Colorado Coll. Studies, vol. 5, pp. 45, 47.
Enallaster texanus Hill and Vaughan, 1898, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, Pl. LIII, figs. 4a–b.
Enallaster texanus Hill, 1901, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 226, Pl. XXVII, figs. 4a–b.
Enallaster sp. Hill, 1901, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 283.

Determinative characters.—Test oblong, cordiform, broad in anterior portion, contracted and truncated posteriorly, with deep anterior groove; upper surface convex, elevated; base flat, depressed at the peristome; sides rounded; apex excentric and posterior. Ambulacra narrow and unequal, the posterolateral pair much shorter than the others. Apical system small and compact. Periproct situated high above the margin.

Dimensions.—Length 16 to 45 millimeters; width 14 to 38 millimeters; height 9 to 27 millimeters.

Description.—The test is oblong, cordiform, and elevated. The upper surface is convex, with a well-defined anterior groove, narrow and slightly depressed at its head. On the posterior face the surface is truncated to the margin. The sides are rounded and inflated. The base is flat, except for the peristonal depression near the anterior margin and the central elevated region extending from the same to the posterior border.

The ambulacra are narrow and very unequal. The antero-lateral pair are large and curved backward in their upper portions. The pores are very unequal; those of the anterior zone are small and near together, those of the posterior elongated, the outer nearly twice as large as the inner series. There are about thirty-five pairs of pores in the petaloidal portion of each poriferous zone.

The postero-lateral pair are short and quite symmetrical in structure. There are sixteen pairs of pores in the petaloidal portions of each poriferous zone.

The anterior unpaired ambulacrum is situated in the anterior groove and is wider than the other areas. An elongated pore appears in the external rows on alternate plates. On the intervening plates the small rows are closely approximated. In the lower portion of each column the plates are large and oblong. A pair of minute pores occupies the lower outer corner of each.

The surface of the test is covered with a minute granulation, scattered among which are numerous small tubercles.

The apical system is small and compact, and the four large genital plates are distinctly perforated. The right anterolateral plate occupies the center of the disk. The five small oculars are wedged in between the genitals.

The peristome is transversely oblong and situated in a depression.

The periproct is situated high upon the truncated posterior margin and is small and oval, acuminate below.

Related forms.—It seems not improbable that *Spatangus columbianum*, described by Lea in 1840, from the United States of Colombia, may prove to be identical, or at least very closely related to the Texan form. The indistinct figure shows a different arrangement of the pores in the anterolateral ambulacra, but it is doubtful whether it can be depended upon for such details of structure.

Enallaster peruvianus, described by Gabb in 1876, from material obtained from Peru, seems to be identical.

Among the European Enallasters none apparently are closely related to *Enallaster texanus*.

Localities.—Very common near Fredericksburg (type), Leon Springs (figured specimen), and at numerous other localities in Texas, and near Inichtea, N. Mex.

Geologic horizon.—Trinity, Fredericksburg, and Washita groups of the Comanche series, Cretaceous.

Collection.—U. S. National Museum (9857).

Enallaster obliquatus Clark.

Plate XL, figures 1a–l.

Enallaster obliquatus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Enallaster obliquatus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 79, 80, Pl. XL, figs. 1a–l.

Determinative characters.—Test oval, cordiform; upper surface convex, flattened and depressed anteriorly, elevated posteriorly; lower surface flat, with peristomial depression; apex forward of the center. Ambulacra narrow, unequal. Surface of the plates covered with small tubercles and intervening microscopic granulation. Apical system compact. Peristome transversely subpentagonal. Periproct situated on truncated posterior margin.

Dimensions.—Length 49 millimeters; width 45 millimeters; height 26.5 millimeters.

Description.—This species has a broad cordiform test, flattened and slanting on the anterior upper surface, whence the name *obliquatus*. The anterior groove is deep, wider at its head, and cuts broadly into the anterior margin. The posterior portion of the test is elevated near the apex and obliquely truncated toward the margin. The sides are sloping anteriorly, fuller posteriorly. The base is flat with a deep peristomial depression.

The ambulacra are narrow and unequal. The anterolateral pair are slightly depressed and curved backward in the upper portion. The pores are unequal, those of the anterior zone small and near together, those of the posterior elongated, the outer much more so than the inner series. There are about 40 pairs of pores in each zone.

The posterolateral pair are short and slightly depressed. The pores are more nearly equal and about 24 pairs are found in each zone. The single ambulacrum is placed in the anterior groove and is much wider than the paired ambulacra. The pores of the different plates vary in size and position. The plates in the lower portions of the areas are large and oblong in form.

The surface of the test is covered with minute tubercles between which is a microscopic granulation. The apical system is small and compact.

The peristome is transversely subpentagonal. The periproct is oval and situated high on the truncated posterior margin.

Related forms.—*E. obliquatus* is separated from *E. texanus*, the only other representative of this genus from the Cretaceous deposits of the United States, by its broader depressed form, more sunken anterior sulcus, and lower position of the periproct. These features seem to be characteristic of nearly all the forms from the Glen Rose beds and perhaps should not be regarded as of specific value. Some specimens more or less intermediate in their characters are

found, and it may perhaps be wiser to regard the difference as varietal rather than specific. This species is related to *E. mexicanus*, described by Cotteau in 1890, from material obtained from Mexico.

Localities.—Near Austin (type) and Glen Rose and other localities in Texas.

Geologic horizon.—Glen Rose limestone of the Trinity group, Comanche series, Cretaceous.

Collections.—U. S. National Museum (12237); Geological Survey of Texas.

Genus HEMIASTER Desor.

Hemiaster elegans Shumard.

Plate XLI, figures 1a–c; Plate XLII, figures 1a–h; Plate XLIII, figures 1a–f.

Hemiaster elegans Shumard, 1853, Pal. Expl. Red River of Louisiana in 1852, p. 210, Pl. II, figs. 4a–c.
Toxaster elegans Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Toxaster elegans Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177) p. 3.
Macraster texanus Roemer, 1888, Neues Jahrb., vol. 1, pp. 191–195, Pl. VI, figs. 1–4.
Epiaster elegans Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Epiaster elegans Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Epiaster elegans Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 80–82, Pl. XLI, figs. 1a–b; Pl. XLII, figs. 1a–b; Pl. XLIII, figs. 1a–e.
Epiaster electus Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 152.
Epiaster elegans Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 152.
Epiaster elegans var. nov. *prænumtius* Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 152.
Epiaster elegans, Hill and Vaughan, 1898, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, Pl. LVI, fig. 3.
Epiaster elegans Hill, 1901, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pp. 226, 251, 260, Pl. XXXVI, fig. 4.

Determinative characters.—Test large, oblong, cordiform, flattened both above and below; sides rounded, with a shallow anterior groove and truncated posterior margin. Ambulacra subpetaloidal, depressed; poriferous zones straight, pores with elongated, slitlike openings. Apical system small. Peristome transversely oval, situated near the anterior margin. Periproct oval, situated on the truncated posterior margin.

Dimensions.—Length 30 to 110 millimeters; width 25 to 100 millimeters; height 15 to 55 millimeters.

Description.—Roemer in 1888 established a new genus and species, *Macraster texanus*, for a form that is identical with *Hemiaster elegans* described by Shumard in 1853. There does not seem to be a sufficiently wide difference between the characters assigned to Macraster and those properly belonging to Hemiaster to warrant the acceptance of the former genus for the present species.

The test is very large and flattened on both the upper and lower surfaces. The sides are round. The groove on the anterior face is shallow and cuts the margin lightly. The posterior face is obliquely but not broadly truncated.

The ambulacral areas are nearly equal, depressed, with a distinct furrow on the upper surface. The poriferous zones are long, wide, and straight, and the pores consist of slitlike openings. The zones are subpetaloidal on the upper surface, reaching quite to the upper margin of the rounded sides. The unpaired ambulacrum is narrower than the others; the pores are smaller and more closely approximated.

The surface of both areas is covered with minute tubercles, between which are microscopic granules.

The apical system is small, compact, and consists of four large perforated genital plates and five small oculars.

The peristome is transversely oval and situated near the anterior margin.

The periproct is large, oval, and situated on the truncated face of the posterior margin.

This and the succeeding species are now referred to the genus Hemiaster, as better material has shown that peripetalous fascioles are present although poorly developed and commonly destroyed on most specimens.

Related forms.—*H. elegans* is most nearly related to *H. whitei*, but is separated from it by its great size, its excessively long subpetaloidal areas, and the position of its periproct, which is on

an obliquely truncated surface that opens downward instead of being, as in *E. whitei*, on a vertical face that opens upward.

Localities.—Fort Washita (type), Fort Worth (figured specimen), and numerous other localities in Texas.

Geologic horizon.—Fort Worth limestone of Washita group, Comanche series, Cretaceous.

Collections.—U. S. National Museum (21887); Johns Hopkins University; Boston Society of Natural History; Geological Survey of Texas.

Hemiaster whitei Clark.

Plate XLIII, figures 2a–c; Plate XLIV, figures 1a–h; Plate XLV, figures 1a–d, 2a–f.

Toxaster elegans Conrad, 1857, U. S. and Mex. Boundary Survey Rept., vol. 1, pt. 2, p. 146, Pl. XXI, figs. 1a–e.[1]
Epiaster whitei Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Epiaster whitei Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Epiaster whitei Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 82, 83, Pl. XLIII, figs. 2a–d; Pl. XLIV, figs. 1a–g.
Epiaster hemiasterinus Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 153.
Epiaster whitei Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 154.
Epiaster hemiasterinus Cragin, 1894, Colorado Coll. Studies, vol. 5, pp. 45, 47.
Epiaster whitei Hill, 1901, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 226.

Determinative characters.—Test small, cordiform; upper surface convex, elevated; lower surface flat; sides inflated; apex forward of the center. Ambulacra moderately broad, petaloidal, pores with elongated openings; anterolateral pair bent slightly backward in upper part. Apical system subcentral. Peristome transversely oval. Periproct small, oval, situated high on posterior border.

Dimensions.—Length 10 to 50 millimeters; width 8 to 45 millimeters; height 16 to 30 millimeters.

Description.—The test is small and cordiform. The upper surface is distinctly elevated, the apex occupying a point anterior to the center. The lower surface is flat with the exception of the peristomial depression. The sides are inflated with a well-marked groove at the center of the anterior face and a prominent truncated surface on the posterior margin.

The ambulacra are moderately broad. The poriferous zones are subpetaloidal in their upper part, but this feature does not continue to the margin. The pores in the paired ambulacra are all of about equal size and equally spaced. In the unpaired ambulacrum they are smaller and nearer together. The anterolateral pair are bent slightly backward in their upper part. They are distinctly larger than the posterolaterals. The interambulacra are prominent and the surface of the plates covered with minute tubercles and microscopic granules. The apical system is small, compact, and consists of four large perforated genital plates and five oculars. The peristome is transversely subpentagonal and situated near the anterior margin. The periproct is small, oval, and situated high on the truncated posterior margin.

Related forms.—In many particulars *Hemiaster whitei* is to be closely associated with *H. elegans*. It is, however, more elevated, its ambulacral furrows are shorter, and its periproct is differently situated. (See p. 88.)

Localities.—Duck Creek, near Denison (type), and numerous other localities in Texas.

Geologic horizon.—Fredericksburg group and lower part of Washita group, Comanche series, Cretaceous.

Collections.—U. S. National Museum (4544, 9732, 31202); Johns Hopkins University.

Hemiaster bexari Clark, n. sp.

Plate XLVI, figures 1a–e.

Determinative characters.—Test small, upper surface nearly flat, elevated, lower surface rounded; sides inflated; apex nearly central, posterolateral ambulacra very short, interambulacra prominent. Peristome small, only slightly depressed, near anterior margin. Periproct small, situated high on truncated surface of posterior margin.

[1] Copied under the name *Hemiaster elegans*.

Dimensions.—Length 22.5 millimeters; width 21.25 millimeters; height 15.5 millimeters.

Description.—This small species has a broad, nearly flat upper surface, rising toward the center, which is slightly elevated. The lower surface is rounded, sloping from near the center in all directions. The sides are inflated.

The ambulacra are unequal, the posterolateral pair being very short. The poriferous zones are broad and shallow and but little depressed. The anterior ambulacrum is broad and shallow. The surface is covered with small tubercles. The peripetalous fasciole is distinct.

The peristome is small, only slightly depressed, and near the anterior margin. The periproct is small and situated high on the truncated surface of the posterior margin.

Locality.—Bexar County, Tex.

Geologic horizon.—Washita group of the Comanche series, Cretaceous.

Collection.—U. S. National Museum (8330).

Hemiaster comanchei Clark, n. sp.

Plate XLVI, figures 2a–d.

Determinative characters.—Test small to medium size, cordiform, high, lower surface flat, sides inflated, apex forward of the center, peripetalous fasciole broad and clearly marked; ambulacra rather narrow, depressed, petaloidal, the posterolateral considerably shorter than the anterolateral, apical system nearly central; peristome near forward margin; periproct small, high on sloping posterior surface, showing clearly from above.

Dimensions.—Length 25 to 60 millimeters; width 22 to 50 millimeters; height 18 to 30 millimeters.

Description.—The test of this species is small to medium sized, cordiform in ambital outline and high. The upper surface is somewhat inflated, the lower surface nearly flat. The sides are inflated. The apex is forward of the center.

The ambulacra are rather narrow and depressed, the poriferous zones petaloidal but narrow, the posterolateral pair being considerably shorter than the anterolateral. The single anterior ambulacrum in a broad, moderately depressed sulcus. The interambulacra are covered with numerous irregularly scattered granules. The peripetalous fascioles are broad and distinct, with granules scattered here and there over the surface. The apical system is nearly central on the upper surface. The peristome is transversely ovate and near the forward margin. The periproct is small, high on sloping posterior surface, and showing clearly from above.

Related forms.—*H. comanchei* is the earliest of the Comanchean hemiasters and possesses certain generalized features which suggest that it is the ancestral form from which *H. whitei*, *H. elegans*, *H. dalli*, and *H. calvini* were derived.

Locality.—Santa Monica Springs, bed of Colorado River, 10 miles west of Austin, Tex.

Geologic horizon.—Glen Rose limestone of Trinity group, Comanche series, Cretaceous.

Collection.—Johns Hopkins University (T 3012).

Hemiaster dalli Clark.

Plate XLVII, figures 1a–f.

Hemiaster dalli Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Hemiaster dalli Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Hemiaster dalli Clark, 1893, U. S. Geol. Survey Bull. 97, p. 89, Pl. XLVIII, figs. 2a–e.

Determinative characters.—Test cordate, subhexagonal, depressed; upper surface with sharp ridges between the ambulacral furrows; base flat; sides rapidly declining; anterior margin deeply grooved. Ambulacra unequal, very deeply depressed on petaloidal portions; anterolateral pair much bent in upper part. Peristome oval, situated on vertically truncated surface of posterior margin.

Dimensions.—Length 45 millimeters; width 45 millimeters; height 21 millimeters.

Description.—This species is much depressed, with distinct marginal angles that give it a subhexagonal outline. Prominent ridges cross the upper surface between the ambulacral furrows. The anterior sulcus cuts deeply into the test and grooves the anterior margin. The sides decline rapidly to the flattened base. The low posterior surface has a nearly vertical truncation of small area.

The ambulacra are very deeply depresssd on the upper surface, a feature much more pronounced than in any other American species. The anterolateral pair are bent backward in their upper part, and have long, deep furrows. The posterolateral pair are about one-half the length of the anterior pair. The single ambulacrum is situated in the broad, deep, anterior sulcus. The poriferous zones in the paired ambulacra are broad, the pores oval, those of each pair united by a shallow furrow. In the unpaired ambulacrum the poriferous zones are narrow, and the pores small and approximated.

The surface is covered with small tubercles with sunken areolas that increase in size toward the base, where they are large, with distinctly perforated mamelons and crenulated bosses. A fine microscopic granulation fills the interspaces.

The apical system is sunken, small, and posterior to the center of the upper surface.

The peristome is transversely oval and close to the anterior margin. The periproct is oval and situated on the truncated surface of the posterior border.

Related forms.—The very deep ambulacral furrows and angular outline readily separate *H. dalli* from any other American species. It is not closely allied to any European form.

Locality.—Bexar County, Tex.

Geologic horizon.—Washita group of the Comanche series, Cretaceous.

Collection.—U. S. National Museum (19114).

Hemiaster calvini Clark.

Plate XLVII, figures 2a–i.

Hemiaster calvini Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Hemiaster calvini Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 90, 91, Pl. XLIX, figs. 2a–i.

Determinative characters.—Test oval, cordate, inflated; upper surface elevated; lower surface flat; posterior margin obliquely truncated. Ambulacra moderately depressed on the upper surface. Peristome transversely oval. Periproct oval, high on truncated posterior border.

Dimensions.—Length 21 to 38 millimeters; width 20 to 35 millimeters; height 16 to 33 millimeters.

Description.—This species has an elevated test that is oval, cordate, and broadly truncated on the posterior margin. The anterior sulcus is shallow and produces but a feeble groove on the anterior margin. The base is flat.

The ambulacra are narrow. The poriferous zones are broad; the petals moderately depressed and of good length; the pores in the petaloidal portions of the paired ambulacra elongated, slitlike, those of the unpaired ambulacrum small and approximated. Beyond the petals the pores are very small, and occupy the lower outside corner of each plate.

The surface of the plates is covered with small perforated tubercles rather widely scattered between which a microscopic granulation intervenes. The peripetalous fasciole is indistinct.

The apical disk is small, compact, and nearly central.

The peristome is small, transversely oval, and situated at a distance from the margin. The periproct is oval and situated high on the truncated surface of the posterior margin.

Related forms.—*H. calvini* is most closely related to *H. whitei*, from which, however, it is distinguished by its more elevated form and its small, narrow, anterior sulcus. The apical system is also more excentric.

Localities.—Shoal Creek (type), near Denison, near El Paso, and other localities in Texas.

Geologic horizon.—Washita group of the Comanche series, Cretaceous.

Collections.—U. S. National Museum (12241); University of Iowa.

Hemiaster parastatus (Morton).

Plate XLVIII, figures 1a–n.

Spatangus sp. Morton, 1830, Am. Jour. Sci., 1st ser., vol. 17, p. 286.
Spatangus cor-marinum (?) Morton, 1830, Am. Jour. Sci., 1st ser., vol. 18, p. 250, Pl. III, fig. 10.
Spatangus cor-marinum (?) Morton, 1830, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, p. 199.
Spatangus parastatus Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 294.
Spatangus parastatus Morton, 1834, Synopsis Organic Remains Cretaceous, p. 77, Pl. III, fig. 21.
Hemiaster parastatus Agassiz and Desor, 1847, Catalogue raisonné, p. 141.
Hemiaster parastatus D'Orbigny, 1847, Prodrome, vol. 2, p. 270.
Spatangus parastatus Bronn, 1848, Index palæontologicus, vol. 1, p. 1160.
Hemiaster parastatus D'Orbigny, 1853–1856, Paléontologie française, vol. 6, p. 265, Pl. DCCCXCIV, fig. 4.
Hemiaster parastatus Desor, 1858, Synopsis des échinides fossiles, p. 373.
Holaster parastatus Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Hemiaster (?) *parastatus* Meek, 1864, Smithsonian Misc. Coll., vol. 7, (177), p. 3.
Hemiaster parastatus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, pl. 77.
Hemiaster parastatus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Hemiaster parastatus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 83, 84, Pl. XLV, figs. 1a–m.
Hemiaster parastatus Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.
Hemiaster parastatus Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 298–300, Pl. XV.
Hemiaster parastatus Slocum, 1909, Field Mus. Nat. Hist. Pub. 134, Geol. ser., vol. 4, No. 1, pp. 9, 10.

Determinative characters.—Test cordiform, inflated; upper surface elevated, with deep groove on anterior surface and sharp ridge posteriorly that is terminated by the flat, nearly vertical, truncated face of the posterior margin. Ambulacral petals depressed, the anterior pair twice as long as the posterior. Apical system small, compact. Peristome with distinct, overhanging lip. Periproct small, situated high on truncated surface.

Dimensions.—Length 37.5 millimeters; width 37.5 millimeters; height 28.12 millimeters.

Description.—This interesting and rather common form has a high, cordiform test, with deep anterior sulcus and high posterior ridge on the upper surface, the latter terminated by the high and nearly vertically truncated face of the posterior margin. The sides are rounded and inflated. The base is flat, with the exception of the peristomial depression.

The ambulacra are very unlike. The poriferous zones are distinctly petaloidal. The petals of the posterolateral pair are short and broad. Those of the anterolateral pair are bent backward at their center, depressed, and about twice the length of the posterolateral pair. The pores are slightly elongated. The unpaired ambulacrum is very broad, the poriferous zones far apart, and the pores small and approximated.

The surface is covered with small tubercles, between which are numerous microscopic granules.

The apical system is small and situated posteriorly to the center of the upper surface. The four genital plates are distinctly perforated and separated by the five small oculars.

The peristome is transversely arched and bilabiate. The lower lip projects prominently. The periproct is small and situated high on the truncated surface of the posterior margin. The peripetalous fasciole is broad and distinct.

Related forms.—*H. parastatus* is most closely related to *H. ungula*, from which, however, it is separated by its deeper and broader anterior sulcus, more posterior position of the apical system and more inflated sides. It is apparently distinct from all of the many species described from European deposits.

Localities.—Gloucester County (type), Timber Creek, and Vincentown (figured specimen), N. J.; Pontotoc, Ala. (Slocum).

Geologic horizon.—Vincentown sand of Rancocas group, New Jersey, and Ripley formation, Alabama; Upper Cretaceous.

Collections.—Academy of Natural Sciences of Philadelphia (1487); American Museum of Natural History, New York; Johns Hopkins University.

Hemiaster stella (Morton).

Plate XLVIII, figures 2a–d.

Spatangus stella Morton, 1830, Am. Jour. Sci., 1st ser., vol.18, p. 245, Pl. III, fig. 11.
Spatangus stella Morton, 1830, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, p. 200.
Spatangus stella Morton, 1834, Synopsis Organic Remains Cretaceous, p. 78, Pl. III, fig. 18.
Hemiaster stella Agassiz and Desor, 1847, Catalogue raisonné, p. 141.
Hemiaster stella Desor, 1858, Synopsis des échinides fossiles, p. 373.
Hemiaster stella Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Hemiaster (?) *stella* Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 3.
Hemiaster wetherbyi De Loriol, 1887, Recueil zool. Suisse, vol. 4, pp. 391–394, Pl. XVII, figs. 5–8.
Hemiaster incrassatus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Hemiaster stella Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Hemiaster stella Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 84, 85, Pl. XLVI, figs. 1a–d.
Hemiaster stella Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.
Hemiaster stella Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 300–301, Pl. XVI, figs. 1–4.

Determinative characters.—Test small, oval, inflated, rounded before, truncated behind; upper surface elevated posteriorly, sloping anteriorly; anterior groove short, not reaching the ambitus. Ambulacra straight, depressed above. Apical system excentric and posterior. Peristome bilabiate and near the anterior border. Periproct small, high above posterior margin. Fasciole distinct.

Dimensions.—Length 25 millimeters; width 21.9 millimeters; height 15.6 millimeters.

Description.—This form was originally described by Morton in 1830, later, in 1833, it was considered by the same writer as the young of the species for which the name *parastatus* was then proposed. *H. incrassatus* is only a large form of *H. stella* and *Hemiaster wetherbyi* is also apparently identical with the same species.

The test is small, oval, and cordate, and much elevated on the posterior portion of the upper surface. The whole test has a rounded, full outline, that is much increased by the absence of the usually deep anterior groove, which in *H. stella* does not reach the margin. The posterior border is nearly vertically truncated.

The ambulacra are depressed in the petaloidal portions which, in the anterolateral pair, are twice as long as in the posterolateral. The poriferous zones are narrow; the pores have transverse slitlike openings. The unpaired ambulacrum is situated in the anterior groove.

The surface of the test is covered with innumerable small tubercles between which is a microscopic granulation. The peripetalous fasciole is very distinct, oval, and passes with a regular curve about the ends of the petaloidal areas. The surface of the test is covered with minute tubercles, between which are microscopic granules. The apical system is small and is situated posteriorly to the center of the upper surface of the test.

The peristome is transversely oval, bilabiate, and placed near the anterior margin. The periproct is small, oval, and is situated at the upper part of the truncated posterior margin.

Related forms.—The shallow anterior groove which falls short of the margin and the full elevated test readily distinguish it from other species.

Localities.—Gloucester (type), near Blackwoodstown (figured specimen), and Timber Creek, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collections.—U. S. National Museum (2208); Academy of Natural Sciences of Philadelphia; Johns Hopkins University.

Hemiaster ungula (Morton).

Plate XLVIII, figures 3a–g.

Spatangus sp. Morton, 1830, Am. Jour. Sci., 1st ser., vol. 17, p. 286.
Spatangus ungula Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 131, Pl. X, fig. 6.
Spatangus ungula Morton, 1834, Synopsis Organic Remains Cretaceous, p. 78, Pl. X, fig. 6.
Micraster ungula Agassiz and Desor, 1847, Catalogue raisonné, p. 141.
Spatangus ungula Bronn, 1848, Index palæontologicus, vol. 1, p. 1161.

Holaster ungula Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Hemiaster ungula Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Hemiaster ungula Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Hemiaster ungula Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 85, 86, Pl. XLVI, figs. 2a–g.
Hemiaster ungula Johnson, 1905, Acad. Nat. Sci. Philadelphia Proc., vol. 57, p. 7.
Hemiaster ungula Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 301–302, Pl. XVI, figs. 5–11.

Determinative characters.—Test oval, cordiform, elevated; upper surface inflated, elevated posteriorly; lower surface flat; sides sloping; anterior sulcus narrow and deep. Ambulacra narrow; poriferous zones straight, depressed, petaloidal. Peripetalous fasciole deeply bent inward between the anterior and posterior paired ambulacra. Apical system small, compact. Peristome transversely oval near anterior margin. Periproct oval, supramarginal.

Dimensions.—Length 31.25 millimeters; width 28 millimeters; height 21.9 millimeters.

Description.—This species has an oval, cordate test, that is very much elevated in the posterior portion. Anteriorly the upper surface slopes rapidly, so that the margin is much thinned down, losing the full round aspect of the previously described forms. The sharp ridge on the posterior portion of the test is terminated by a nearly vertical truncation of the posterior margin. The base is flat, save for the peristomial depression.

The ambulacra are narrow. The poriferous zones are petaloidal, straight, and deeply depressed on the upper surface. The unpaired ambulacrum is placed in the anterior sulcus and but slightly exceeds the other areas in width. The petals of the anterolateral pair are twice the length of the posterolateral. The pores of the paired ambulacra are elongated and separated, those of the single ambulacrum small, oval, and approximated.

The surface of the test is covered with small tubercles, between which are numerous minute granules. The peripetalous fasciole is distinct and bent outward between the anterior and posterior paired ambulacra.

The apical system is small and situated posterior to the center of the upper surface. The right anterolateral genital plate is very large and widely separates the posterior pair of oculars. The posterolateral genitals have large perforations.

The peristome is transversely oval, bilabiate, with a prominently projecting lower lip. The periproct is large and is situated at the upper part of the truncated face of the posterior margin.

Related forms.—It is separated from *H. parastatus*, with which it is found, by the narrower anterior groove, more central apical system, less inflated sides and sharper posterior keel.

Localities.—Chesapeake & Delaware Canal (type), and Timber Creek and Vincentown, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collections.—Academy of Natural Sciences of Philadelphia (1503); American Museum of Natural History, New York; Johns Hopkins University.

Hemiaster texanus Roemer.

Plate XLIX, figures 1a–j.

Hemiaster texanus Roemer, 1849, Texas, p. 393.
Hemiaster texanus Roemer, 1852, Die Kreidebildungen von Texas, p. 85, Pl. X, fig. 4.
Hemiaster americanus Gabb, 1853, Naturwiss. Ver. in Halle Jahresb., pp. 372, 373.
Hemiaster texanus Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Hemiaster texanus Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 3.
Hemiaster texanus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Hemiaster texanus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Hemiaster texanus Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 86, 87, Pl. XLVII, figs. 1a–i.
Hemiaster texanus Cragin, 1893, Geol. Survey Texas Fourth Ann. Rept., p. 155.
Hemiaster texanus Aguilera, 1897, Inst. geol. México Bol. Nos. 4, 5, 6, p. 215.
Hemiaster texanus Hill and Vaughan, 1898, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, Pl. LXI, figs. 1a, 1b.
Hemiaster ? texanus Bosé, 1899, Inst. geol. México Bol. No. 3, p. 11.
Hemiaster texanus Hill, 1902, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, Pl. XLV, fig. 5.

Determinative characters.—Test oval, cordate, declining anteriorly, elevated slightly posteriorly; anterior sulcus broad and deep, producing groove in margin. Ambulacra broadly depressed on upper surface; antero-lateral pair bent backward in upper part; unpaired ambulacrum very broad. Apical system compact, the four genitals distinctly perforated. Peristome large, transversely oval, bilabiate. Periproct large, oval, at center of truncated surface of posterior margin.

Dimensions.—Length 22 to 38 millimeters; width 21 to 36 millimeters; height 15 to 20 millimeters.

Description.—This important species is broadly cordate and slightly depressed on the upper surface; base flat. Posterior to the apex there is a sharp ridge that declines gradually toward the obliquely truncated margin. Anteriorly the upper surface declines toward the anterior border.

The ambulacra are broad, very unequal, and depressed in the petaloidal portions. The poriferous zones are broad, the pores of the paired ambulacra elongated, those of the single ambulacrum round and approximated. The petals of the anterolateral pair are bent backward in their upper part and are nearly twice the width of the posterolateral pair. The single ambulacrum is very broad, the poriferous zones widely separated.

The surface of the test is covered with small tubercles that are perforated and for the most part crenulated. A microscopic granulation fills the intertubercular space.

The apical system is small and compact and situated near the center. The four genital plates are distinctly perforated; the right anterolateral is larger than the others and serves as the madreporite. The five oculars are wedged between the genitals and are deeply cut by the upper portions of the ambulacra.

The peristome is large, transversely oval, and bilabiate. The periproct is large, oval, and situated in the center of the truncated surface of the posterior margin.

Related forms.—Under the name of *Hemiaster americanus*, Giebel published in 1853 the description of a new species of Hemiaster which he states can be with difficulty distinguished from *H. texanus*. It is considered identical in the present report since the differences seem hardly to warrant the establishment of a new species. *Periaster australis*, described by Gabb from Peru, as far as the figures and description show, must be a Hemiaster, and to all appearances is closely allied if not identical with *H. texanus*.

Localities.—At waterfall of Guadalupe below New Braunfels (type), Fairview (figured specimen), and Austin, Tex.

Geologic horizon.—Austin chalk, Upper Cretaceous.

Collections.—U. S. National Museum; Johns Hopkins University (T 3013).

Hemiaster humphreysanus Meek and Hayden.

Plate XLIX, figures 2a–f.

Hemiaster (?) *humphreysanus* Meek and Hayden, 1857, Acad. Nat. Sci. Philadelphia Proc., vol. 9, pp. 147, 148.
Hemiaster (?) *humphreysanus* Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Hemiaster (?) *humphreysanus* Meek, 1864, Smithsonian Misc. Coll., vol. 7 (177), p. 3.
Hemiaster humphreysanus Meek, 1876, U. S. Geol. and Geog. Survey Terr. Final Rept., vol. 9, pp. 5, 6, Pl. X, figs. 1a–g.
Hemiaster humphreysanus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Hemiaster humphreysanus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Hemiaster humphreysanus Clark, U. S. Geol. Survey Bull. 97, p. 88, Pl. XLVIII, figs. 1a–f.

Determinative characters.—Test oval, cordate; upper surface high, flat, with broad, vertical truncation on posterior margin, and long anterior groove; base flat; sides rounded. Ambulacra in deep furrows that reach to the edge of the elevated sides. Apical system large and compact, posteriorly situated. Peristome small, transversely oval, and bilabiate. Periproct oval, situated high on posterior margin.

Dimensions.—Length 32.5 millimeters; width 31.5 millimeters; height 20.5 millimeters.

Description.—The absence of distinct fascioles on the type specimens of this species caused Meek and Hayden to place it doubtfully in the genus Hemiaster, to which beyond doubt it belongs. The test is full, the sides rounded, and the high upper surface distinctly flattened. The base is

also flat, with the exception of the peristomial depression. The situation of the apex so far posterior to the center of the upper surface produces a long anterior sulcus, that grooves the anterior margin. A high, vertically truncated surface terminates the posterior margin.

The ambulacra are broad, very unequal, and deeply depressed on the upper surface. The petals of the posterolateral pair are very short, those of the anterolateral very long, the latter quite three times the length of the former. The unpaired ambulacrum occupies the long anterior sulcus. The anterolateral pair are bent backward in the upper part and forward in the lower. The poriferous zones are broad, the pores distinct and oval. Since much of the surface of the test has suffered removal the character of the tubercles and granules can not be fully determined.

The apical system, which in the specimen examined has been largely destroyed, was evidently large, compact, and situated far posterior to the center of the upper surface.

The peristome is small and situated near the anterior margin. The periproct is oval and situated on the vertically truncated surface of the posterior margin.

Related forms.—*H. humphreysanus* is a unique form and is not related to any species of Hemiaster hitherto described.

Locality.—One hundred and fifty miles from the mouth of the Yellowstone River in Montana (Meek and Hayden).

Geologic horizon.—Pierre shale, of Montana group, Upper Cretaceous.

Collection.—U. S. National Museum (331).

Hemiaster californicus Clark.

Plate L, figures 1a–d.

Hemiaster californicus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Hemiaster californicus Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Hemiaster californicus Clark, 1893, U. S. Geol. Survey Bull. 97, p. 90, Pl. XLIX, figs. 1a–c.

Determinative characters.—Test small, subquadrate, depressed; upper surface flat, with shallow anterior sulcus, sloping sides, and low truncated posterior margin; lower surface flat. Ambulacra depressed, in shallow furrows. Apical system small, posterior to center. Peristome transversely oval near anterior margin. Periproct situated on the low truncated surface of the posterior margin.

Dimensions.—Length 28 millimeters; width 27 millimeters; height 11 millimeters.

Description.—This form has the details of its structure poorly preserved in the specimens examined, although it belongs, beyond much doubt, to the genus Hemiaster. The test is small, much depressed, and subquadrate in ambital outline. It is broader anteriorly, with a feeble groove in the center of the anterior margin. The posterior portion of the test is but slightly more elevated than the anterior, and the truncated margin is low and narrow. The base is flat, with the exception of the peristomial depression.

The ambulacra are but slightly depressed in the petaloidal portions. The poriferous zones are broad, and the oval pores are united by shallow furrows. The apical system is small and situated slightly forward of the center. The peristome is transversely oval and situated near the anterior margin. The periproct is small, oval, and situated on the low, truncated surface of the posterior border.

Related forms.—From its shallow ambulacral furrows, *Hemiaster californicus* may be compared to *H. humphreysanus*, but is readily separated from it because of its more central apical system and its depressed form.

Locality.—Redding, Shasta County, Cal.

Geologic horizon.—Chico formation, Upper Cretaceous.

Collection.—U. S. National Museum (31203).

Hemiaster beecheri Clark, n. sp.

Plate L, figures 2a–c.

Determinative characters.—Test large, cordiform, elevated; upper surface inflated, depressed posteriorly; ambulacra broadly depressed on dorsal surface, anterior ambulacrum in broad sulcus.

Dimensions.—Length 70 (?) millimeters; width 59 millimeters; height 41 millimeters.

Description.—This large species is represented by a single specimen. The test is cordiform in ambital outline and elevated. The upper surface is much inflated, sloping rapidly to the sides and toward the posterior margin, which is much depressed. The ambulacra are deeply depressed, in broad grooves which distinctly affect the ambital outline. The interambulacra form projecting ridges, the posterior interambulacrum producing a sharp crest. The apical system is situated in a pronounced apex anteriorly. The peristome is located in a well-marked depression near the anterior margin.

Locality.—Sage Creek, S. Dak.

Geologic horizon.—Pierre shale of Montana group, Upper Cretaceous.

Collection.—Peabody Museum, Yale University (1863).

Hemiaster lacunosus Slocum.

Plate L, figures 3a–d; Plate LI, figures 1a–i.

Hemiaster lacunosus Slocum, 1909, Field Mus. Nat. Hist. Pub. 134, Geol. ser., vol. 4, No. 1, pp. 10, 11, Pl. II, figs. 1–7.

Determinative characters.—Test small, indistinctly cordate, upper surface slightly convex, elevated posteriorly; sides inflated; lower surface nearly flat. Ambulacra narrow, poriferous zones not deeply depressed the posterolateral pair being quite short. Peripetalous fasciole distinct. Peristome large, near anterior margin. Periproct high on posterior truncated surface.

Dimensions.—Length 17.8 to 23.4 millimeters; width 16.3 to 23.6 millimeters; height 11.8 to 17 millimeters.

Description.—Slocum says:

> Test small, indistinctly cordate, ventral surface moderately convex, dorsal surface convex, strongly elevated in the posterior interambulacral area and gradually sloping with an indistinct anterior sulcus; anterior and lateral borders inflated, posterior margin truncated. Ambulacral areas petaloid, with straight petals situated in depressions of the surface, the anterolateral pair nearly twice as long as the posterolateral pair; poriferous zones of the paired petals wide, pores transversely elongate and situated far apart. Anterior petal longer but narrower than the others and situated in a deep depression which grades into an indistinct anterior sulcus; poriferous zones of this petal narrow and far apart; pores small, round, and separated by a tubercle. Interambulacral areas broad and composed of large plates. Surface of the test covered with a multitude of small tubercles with sunken areoles that increase in size toward the peristome. The tubercles have perforated mamelons and crenulated bosses, the interspaces being filled with microscopic granulations. Peripetalous fasciole wide and distinct, moderately bent inward between the petaloid areas except the two posterior ones. Apical disk sunken, small, and situated somewhat posterior to the center of the dorsal surface, the four genital plates distinctly perforated and separated by five small radial plates. Right anterior genital plate large, convex and forming the madreporite. Peristome transversely arched, bilabiate, with prominent labrum. Periproct about the size of the peristome, elongated vertically and situated near the top of the posterior truncation.
>
> *Related forms.*—*H. lacunosus* resembles *H. parastatus* in general form and proportions, but is distinguished from that species by its smaller size and by the sunken areoles of the tubercles. Moreover, the posterior interambulacral area is rounded, while in *H. parastatus* it is in the form of a ridge. *H. lacunosus* is similar to *H. stella* in size, but differs from it in the shape of the fasciole, the sunken areoles and the form of the anterior margin. It resembles *H. dalli* in having sunken areoles, but in general form these two species are quite dissimilar. The specific name adopted refers to the sunken areoles by which the species is distinguished.

Locality.—Pontotoc and Houston, Miss.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collections.—U. S. National Museum (31204); Field Museum (P 10342).

Hemiaster kümmeli Clark.

Plate LII, figures 1a–c.

Hemiaster kümmeli Clark, 1907, in Weller, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 303–304, Pl. XVII, figs. 1–3.

Determinative characters.—Test cordate, slightly elevated. Upper surface nearly flat, with weakly depressed petaloidal areas; the lower surface flat. Peristome with distinct overhanging lip.

Dimensions.—Length 30 to 55 millimeters; width 30 to 40 millimeters; height about 20 millimeters.

Description.—This species is represented by numerous flattened casts, none of which show clearly the original form of the test, although it is apparently somewhat flatter than the other New Jersey Cretaceous Hemiasters. The test is relatively large. It is but slightly elevated with a somewhat flattened upper surface.

The ambulacra are pronounced, with weakly depressed petaloidal areas. The unpaired, posterior interambulacrum is nearly flat with a low truncated posterior surface. The petals of the posterolateral pair are relatively long and narrow and less than twice the length of the anterolateral pair. The unpaired ambulacrum is not deeply depressed and does not form a pronounced sulcus on the anterior margin. The apical system is small but not as strongly excentric as in some of the other Cretaceous species. The peristome has a distinct overhanging lip. The peripetalous fascioles can not be seen.

Related forms.—This species is related to both *H. parastatus* and *H. welleri*. From the former it is separated by its shallower and narrower ambulacral petals and less elevated form; from the latter by its longer and narrower posterolateral ambulacral petals and flatter form.

Locality.—Lorillard clay pits near Keyport, N. J.

Geologic horizon.—Woodbury clay of Matawan group, Upper Cretaceous.

Collections.—Geological Survey of New Jersey; Johns Hopkins University.

Hemiaster welleri Clark.

Plate LII, figures 2a–c.

Hemiaster welleri Clark, 1907, in Weller, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 302–303, Pl. XVII, figs. 4–6.

Determinative characters.—Test cordiform, inflated; upper surface only slightly elevated posteriorly; lower surface flat; sides rounded. Ambulacra depressed. Apical system small. Peristome with distinct overhanging lip. Periproct small, high on posterior truncated surface.

Dimensions.—Length 27 millimeters; width 24 millimeters; height 17 millimeters.

Description.—This species has afforded few specimens, and those for the most part casts, but it is evidently distinct from the other forms described. The test is moderately high, clearly cordiform, and with depressed ambulacra. The anterior sulcus is broad and clearly defined but does not deeply indent the anterior ambitus. The posterior ridge is not greatly accentuated and terminates in a well-defined, truncated posterior surface. The sides are rounded. The lower surface is slightly inflated.

The ambulacra are moderately depressed in their petaloidal portions, the posterolateral pair being considerably shorter than the anterolateral, although the difference is less marked in this species than in the other New Jersey Cretaceous Hemiasters. The anterior ambulacrum is in a broad shallow groove that largely disappears before the ambitus is reached.

The apical system is small and imperfectly shown on the casts from which its characters can be alone obtained.

The peristome is of moderate size with distinct overhanging lip. The periproct is small and situated high on the truncated posterior surface.

Related forms.—*Hemiaster welleri* is related to *H. parastatus* from which, however, it is separated by its less deeply depressed ambulacral furrows and less elevated upper surface. It also shows points of resemblance to *H. kummeli* from which, however, it is separated by its lower posterolateral ambulacral petals and less elevated posterior ridge on the upper surface.

Localities.—Railroad cut 1 mile south of Lower Jamesburg (type); 3 miles east of Jamesburg; Reeves clay pit; Lenola; bluff east of Atlantic Highlands, N. J.

Geologic horizon.—Merchantville clay of Matawan group and Navesink marl of Monmouth group, Upper Cretaceous.

Collections.—Geological Survey of New Jersey; Johns Hopkins University.

Genus LINTHIA Merian.

LINTHIA TUMIDULA Clark.

Plate LIII, figures 1a–i.

Linthia tumidula Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Linthia tumidula Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, No. 103, p. 52.
Linthia tumidula Clark, 1893, U. S. Geol. Survey Bull. 97, pp. 91, 92, Pl. I, figs. 1a–i.
Linthia tumidula Weller, 1907, Cretaceous paleontology of New Jersey: Geol. Survey New Jersey, pp. 304–305, Pl. XVIII, figs. 1–9.

Determinative characters.—Test oval, cordiform, elevated; apex central; posterior border obliquely truncated, anterior portion grooved by narrow sulcus; sides sloping. Ambulacral furrows long, straight, depressed; poriferous zones broad, pores oval. Apical system small, nearly central. Periproct on truncated posterior border. Peripetalous and lateral fascioles distinct.

Dimensions.—Length 53 millimeters; width 50 millimeters; height 28 millimeters.

Description.—This large form has an elevated test, with flattened, sloping sides, oval outline, and a narrow, moderately depressed, anterior sulcus that grooves the anterior margin. The base is flat, except for the peristomial depression.

The ambulacra are narrow and furrow for a long distance the upper surface of the test to a moderate depth. The poriferous zones are broad and straight. The pores are large and oval, and those of each pair connected by a shallow furrow. The anterolateral petals reach far down the sloping sides and are about one and one-half times as long as the posterolateral pair.

The surface of the test is covered with minute, perforated tubercles that are much longer on the base than on the upper surface. A microscopic granulation fills the space between the tubercles. Both the peripetalous and lateral fascioles can be readily traced. The apical system is small, nearly central, and slightly depressed. The peristome is transversely oval and situated near the anterior margin. The periproct is small, oval, and situated but a short distance above the posterior margin.

Localities.—Timber Creek and Vincentown, N. J.

Geologic horizon.—Vincentown sand of Rancocas group, Upper Cretaceous.

Collections.—American Museum of Natural History, New York; Boston Society of Natural History; Johns Hopkins University.

LINTHIA VARIABILIS Slocum.

Plate LIV, figures 1a–l.

Linthia variabilis Slocum, 1909, Field Mus. Nat. Hist. Pub. 134, Geol. ser., vol. 4, No. 1, pp. 12–14, Pl. III, figs. 1–11.

Determinative characters.—Test cordate, upper surface elevated, under surface nearly flat, sides inflated, apex nearly central. Ambulacra in relatively deep depressions. Peristome near anterior margin. Periproct near top of posterior truncation.

Dimensions.—Length 17.1 to 31.6 millimeters; width 16.6 to 29.1 millimeters; height 10.1 to 19.6 millimeters.

Description.—Slocum says:

> Test distinctly cordate, truncated posteriorly, ventral surface depressed convex, dorsal surface elevated, forming a sharp ridge in the posterior interambulacral area. Sides inflated and sloping to the lateral and anterior margins, posterior truncation slightly concave and the angle between the truncation and the base line varying from 77° to 90°. Ambulacral areas straight, petaloid, situated in comparatively deep depressions of the dorsal surface. Anterolateral pair about one and one-half times the length of the posterolateral pair, poriferous zones of these four petals wide, pores elongated and slitlike. Each pair of pores connected by a shallow groove and the pore near the border of the petal the larger. Unpaired anterior ambulacral area situated in a deep depression the continuance of which forms a sulcus in the anterior margin. Poriferous zones of this area narrow and situated far apart. Pores round and each pair separated by a tubercle. Interambulacral areas broad and composed of large plates. Surface of the test covered with

minute perforated tubercles having crenulated bosses. The tubercles increase in size as they approach the peristome. Interspaces filled with small tubercles and microscopic granulations. Both peripetalous and lateral fascioles are clearly defined, peripetalous fasciole decidedly bent inward between the anterolateral and posterolateral petals and somewhat less so between the other petals. Apical system situated in the center or somewhat anterior to the center of the dorsal surface, small, depressed, having the four genital plates perforated and separated by five small radials. Peristome transversely elliptical, situated near the anterior margin. Labrum prominent. Periproct somewhat elongated vertically and situated near the top of the posterior truncation.

Related forms.—*L. tumidula,* the only other species of this genus hitherto described from the American Cretaceous, is so unlike *L. variabilis* that detailed comparison is unnecessary.

Localities.—Onemile Run, Pontotoc, and Tippah County, Miss.

Geologic horizon.—Ripley formation, Upper Cretaceous.

Collection.—Field Museum, Chicago (P 10457).

PART II.—THE CENOZOIC ECHINODERMATA.

By William Bullock Clark and Mayville W. Twitchell.

INTRODUCTION.

GEOLOGIC AND GEOGRAPHIC RANGE.

The Cenozoic Echinodermata discussed in the succeeding pages, although largely confined to the Eocene, are by no means absent from later deposits. The Eocene forms are very abundant and embrace some of the most diagnostic fossils of that age, but they are less common than in the Cretaceous. They are found at several Eocene horizons on the Atlantic and Pacific coasts, but are more numerous and characteristic in the Eocene of the South Atlantic and Gulf Coastal Plain, where they occur in large numbers. Nearly all that have been collected belong to the group Echinoidea, although representatives of Crinoidea, Asteroidea, and Holothuroidea have been found. Among the echinoid genera recognized are Cidaris, Cœlopleurus, Echinocyamus, Fibularia, Scutella, Mortonella, Periarchus, Clypeaster, Echinanthus, Cassidulus, Breynella, Echinolampas, Hemipatagus, Brissopsis, Linthia, Schizaster, Eupatagus, Macropneustes, and Sarsella.

The Oligocene strata of the South Atlantic and Gulf areas have in few places been satisfactorily delimited from the Eocene, so that the age of some of the echinoid material can not be determined with certainty. Among the known Oligocene genera of the South Atlantic and Gulf areas are Cidaris, Echinocyamus, Laganum, Amblypygus, Oligopygus, Cassidulus, Echinolampas, Agassizia, Schizaster, and Eupatagus. The great majority of the forms come from Florida. The Oligocene deposits of California have also furnished specimens of Cidaris.

The Miocene deposits of both the Atlantic and Pacific coasts have afforded a considerable number of echinoderms, chiefly echinoids. The Atlantic coast Miocene contains Ophioderma (?), Cidaris, Cœlopleurus, Psammechinus, Scutella, Mellita, Encope, Cassidulus, Agassizia, Brissus, Plagionotus, and Echinocardium. The Pacific coast Miocene has furnished Asterias, Amphiura, Cidaris, Scutella, Dendraster, Astrodapsis, Scutaster, Clypeaster, and Linthia.

The Pliocene deposits contain very few echinoderms. On the South Atlantic coast from the Carolinas southward a few forms have been recognized, among them Strongylocentrotus, Encope, and Diplothecanthus. On the Pacific coast Dendraster, Astrodapsis, and Schizaster (?) are found. The Miocene and Pliocene echinoids of the Pacific coast have been found to be of more than ordinary value in the determination of geologic horizons. This is due to their limited geologic range and to the fact that, where present at all, they are usually abundant and well preserved.

The Pleistocene deposits likewise have furnished very few echinoderms, and those for the most part of species living in the adjacent seas. Among those recognized from the Atlantic border have been Asterias, Strongylocentrotus, Mellita, Moira, and Toxopneustes. On the Pacific coast, on the other hand, several species of Strongylocentrotus and Dendraster are found.

The absence of species identical with those of other continents and particularly of Europe renders it impossible to attempt detailed correlation of American and foreign horizons. Genera represented in the main divisions of the Cenozoic in America are with scarcely an exception similar to those typical of the same divisions elsewhere.

The accompanying tables show the stratigraphic position of the more important American Cenozoic formations, the geologic distribution of the Cenozoic Echinodermata of the United States, and the distribution of eastern Gulf Eocene and Oligocene Echinodermata.

Stratigraphic position of the more important American Cenozoic formations.

[Vertical parallel lines indicate formations which occur in separate areas and whose exact equivalence is not established.]

Series.	Pacific border (California).	Eastern Gulf area.	South Atlantic border.	Middle Atlantic border.
Pleistocene	San Pedro		Columbia: Satilla, Okefenokee	Columbia: Talbot: Pamlico, Chowan; Wicomico; Sunderland; ‖ Coharie
Pliocene?		Lafayette ?	Lafayette?	Lafayette
Pliocene	Merced, San Diego	Caloosahatchee ‖ Nashua	Waccamaw	Waccamaw
Miocene	San Pablo, Santa Margarita, Monterey, Vaqueros	Pascagoula; Jacksonville ‖ Choctawhatchee	Duplin; Edisto ‖ Marks Head	Chesapeake: Yorktown, St. Marys, Choptank ‖ Cohansey, Calvert ‖ Kirkwood
Oligocene	San Lorenzo	Apalachicola: Alum Bluff: Shoal River, Oak Grove, Chipola; Chattahoochee ‖ Tampa. St. Stephens Island.: Vicksburg	Apalachicola: Alum Bluff; Chattahoochee. Vicksburg	
Eocene	Tejon; Martinez	St. Stephens Island.: Jackson. Claiborne: Gosport, Lisbon, Tallahatta. Wilcox: Hatchetigbee, Bashi, Tuscahoma, Nanafalia. Midway: Naheola, Sucarnochee, Clayton	Jackson ‖ Cooper. Claiborne: Santee, Congaree. Wilcox ‖ Williamsburg. Midway ‖ Black Mingo	Castle Hayne. Trent. Pamunkey: Nanjemoy, Aquia. Shark River

Geologic distribution of the Cenozoic Echinodermata of the United States.

	Eocene.	Oligocene.	Miocene.	Pliocene.	Pleistocene.
Crinoidea:					
Dicyclica—					
Flexibilia—					
Pinnata—					
Antedoniæ—					
Zenometra (?) conoideus (Emmons)	×				
Stelleroidea:					
Asteroidea—					
Cryptozonia—					
Asteriidæ—					
Asterias (?) sp	×				
Asterias remondii Gabb			×		
Asterias stellionura Poiret					
Asterias linckii Müller					
Ophiuroidea—					
Zygophiuræ—					
Ophiodermatidæ—					
Ophioderma (?) sp			×		
Amphiuridæ—					
Amphiura sanctacrucis Arnold			×		
Echinoidea:					
Regularia endobranchiata—					
Cidaroidea—					
Cidaridæ—					
Cidaris mitchelli Emmons	×				
Cidaris carolinensis Emmons	×				
Cidaris pratti Clark	×				
Cidaris merriami Arnold	×				
Cidaris mœreus de Gregorio	×				
Cidaris modestus de Gregorio	×				
Cidaris ordinatus de Gregorio	×				
Cidaris perdubius de Gregorio	×				
Cidaris blandis de Gregorio	×				
Cidaris alabamensis Morton	×				
Cidaris sp	×				
Cidaris mortoni Conrad		×			
Cidaris smithi Clark		×			
Cidaris georgiana Clark		×			
Cidaris branneri Arnold		×			
Cidaris thouarsii (?) Valenciennes			×		

Geologic distribution of the Cenozoic Echinodermata of the United States—Continued.

	Eocene.	Oligocene.	Miocene.	Pliocene.	Pleistocene.
Echinoidea—Continued.					
Regularia ectobranchiata—					
Diademoidea—					
Arbacina—					
Arbacidæ—					
Cœlopleurus infulatus (Morton)					
Cœlopleurus aldrichi Clark					
Cœlopleurus improcerus (Conrad)					
Cœlopleurus sloani Clark					
Echinocidaris sp. McCrady					
Diademina—					
Cyphosomatidæ—					
Orthechinus pretiosus Clark					
Echinina—					
Tripiechinidæ—					
Echinus exereeus de Gregorio					
Echinus (?) sp.					
Gagaria americana					
Psammechinus philanthropus (Conrad					
Psammechinus exoletus McCrady					
Toxopneustes virgiegatus (Lamarck)					
Strongylocentrotidæ—					
Strongylocentrotus dröbachiensis (Müller)					
Strongylocentrotus franciscanus A. Agassiz					
Strongylocentrotus purpuratus (Stimpson)					
Irregularia—					
Gnathostomata—					
Clypeastrina—					
Fibularidæ—					
Echinocyamus parvus Emmons					
Echinocyamus huxleyanus Meyer					
Echinocyamus texanus Twitchell					
Echinocyamus vaughani Twitchell					
Sismondia (?) plana Conrad					
Sismondia (?) arnoldi Twitchell					
Sismondia (?) coalingaensis Twitchell					
Fibularia meridionalis (Meyer)					
Laganidæ—					
Laganum (?) crustuloides (Morton)					
Laganum eldridgei Twitchell					
Laganum archerensis Twitchell					
Laganum johnsoni Twitchell					
Laganum floridanum Twitchell					
Laganum dalli Twitchell					
Scutellidæ—					
Scutella mississippiensis Twitchell					
Scutella tuomeyi Twitchell					
Scutella (?) conradi (Cotteau)					
Scutella andersoni Twitchell					
Scutella fairbanksi Pack					
Scutella (?) merriami (Anderson)					
Scutella norrisi Pack					
Scutella aberti Conrad					
Scutella gabbi (Rémond) Merriam					
Mortonella quinquefaria (Say)					
Periarchus altus Conrad					
Periarchus lyelli Conrad					
Periarchus protuberans Twitchell					
Periarchus pileus-sinensis (Ravanel)					
Dendraster perrini (Weaver)					
Dendraster arnoldi Twitchell					
Dendraster gibbsii (Rémond)					
Dendraster oregonensis (Clark)					
Dendraster coalingaensis Twitchell					
Dendraster interlineatus (Stimpson)					
Dendraster excentricus (Eschscholtz)					
Astrodapsis antiselli Conrad					
Astrodapsis arnoldi Twitchell					
Astrodapsis whitneyi Rémond					
Astrodapsis tumidus Rémond					
Astrodapsis jacalitosensis Arnold					
Astrodapsis fernandoensis Pack					
Mellita caroliniana Ravenel					
Mellita pentapora Gmelin					
Scutaster andersoni Pack					
Encope macrophora Ravenel					
Clypeastridæ—					
Clypeaster rogersi (Morton)					
Clypeaster bowersi Weaver					
Clypeaster (?) brewerianus (Rémond)					
Diplothecanthus dalli Twitchell					
Diplothecanthus rosaceus (Lamarck)					
Echinanthus georgiensis Twitchell					
Atelostomata—					
Asternata—					
Nucleolitidæ—					
Amblypygus merrilli Twitchell					
Oligopygus wetherbyi De Loriol					
Oligopygus haldermani (Conrad)					
Oligopygus floridanus Twitchell					
Cassidulida—					
Cassidulus californicus F. M. Anderson					
Cassidulus (Rhynchopygus) (?) holmesi Twitchell					
Cassidulus (Rhynchopygus) lyelli (Conrad)					
Cassidulus (Rhynchopygus) raveneli Twitchell					
Cassidulus (Rhynchopygus) patelliformis Bouvé					
Cassidulus (Rhynchopygus) depressus Twitchell					

Geologic distribution of the Cenozoic Echinodermata of the United States—Continued.

	Eocene.	Oligocene.	Miocene.	Pliocene.	Pleistocene.
Echinoidea—Continued.					
Irregularia—Continued.					
Atelostomata—Continued.					
Asternata—Continued.					
Cassidulidæ—Continued.					
Cassidulus (Pygorhynchus) conradi Conrad	(?)	(?)			
Cassidulus (Pygorhynchus) carolinensis Twitchell	×				
Cassidulus (Pygorhynchus) georgiensis Twitchell	(?)	×			
Cassidulus (Pygorhynchus) gouldii Bouvé	(?)	×			
Cassidulus (Pygorhynchus) alabamensis Twitchell		×			
Cassidulus bassleri Twitchell			×		
Cassidulus berryi Twitchell					
Breynella gregoryi Twitchell					
Echinolampas appendiculatus Emmons					
Echinolampas aldrichi Twitchell					
Sternata—					
Spatangidæ—					
Hemipatagus argutus Clark					
Hemipatagus subrostratus Clark	×				
Schizaster lecontei Merriam	×				
Schizaster armiger Clark					
Schizaster sp.	×				
Schizaster floridanus Clark					
Schizaster americana Clark					
Schizaster (?) stalderi Weaver					
Schizaster atropos (Lamarck)					×
Linthia wilmingtonensis Clark					
Linthia alabamensis Clark					
Linthia (?) californica Weaver					
Eupatagus carolinensis Clark					
Eupatagus floridanus Clark		×			
Brissopsis rimulatus Ravenel					
Macropneustes carolinensis Clark					
Macropneustes mortoni (Conrad)	×				
Sarsella gregoryi Clark	×				
Spatangus (?) pachecoensis Pack					
Agassizia conradi (Bouvé)					
Agassizia porifera (Ravenel)			×		
Echinocardium orthonotum Conrad			×		
Echinocardium depressum Clark			×		
Echinocardium gothicus (Ravenel)			×		
Brissus spatiosus (Ravenel)			×		
Metalia ravenelianus McCrady			×		
Metalia holmesi McCrady			×		
Holothurioidea:					
Paractinopoda—					
Synaptidæ—					
Chiridota sp.		×			
Synapta sp.		×			

Stratigraphic distribution of eastern Gulf Eocene and Oligocene Echinodermata.

	Eocene.				Oligocene.	
	Midway.	Wilcox.	Claiborne.	Jackson.	Vicksburg.	Apalachicola.
Cidaris blandis de Gregorio			×			
Cidaris ordinatus de Gregorio			×			
Cidaris perdubius de Gregorio			×			
Cidaris mœreus de Gregorio			×			
Cidaris modestus de Gregorio			×			
Cidaris alabamensis Morton						
Cidaris sp.						
Cidaris mortoni Conrad					×	
Cidaris smithi Clark						
Cidaris georgiana Clark						
Coelopleurus aldrichi Clark						
Orthechinus pretiosus Clark						
Gagaria americana Clark						
Echinus exerceus de Gregorio			×			
Echinus sp.						
Echinocyamus huxleyanus Meyer						
Echinocyamus texanus Twitchell						
Echinocyamus vaughani Twitchell					×	
Fibularia meridionalis (Meyer)			×			
Laganum eldridgei Twitchell					×	
Laganum archerensis Twitchell					×	
Laganum johnsoni Twitchell					(?)	
Laganum floridanum Twitchell					×	
Laganum dalli Twitchell					×	
Scutella mississippiensis Twitchell						
Mortonella quinquefaria (Say)			×	(?)		
Periarchus lyelli Conrad			×	×		
Periarchus protuberans Twitchell						
Periarchus pileus-sinensis (Ravenel)				×	(?)	
Clypeaster rogersi (Morton)						
Echinanthus georgiensis Twitchell	×					
Amblypygus merrilli Twitchell						
Oligopygus wetherbyi De Loriol					×	
Oligopygus haldermani (Conrad)						

Stratigraphic distribution of eastern Gulf Eocene and Oligocene Echinodermata—Continued

	Eocene.				Oligocene.	
	Midway.	Wilcox.	Claiborne.	Jackson.	Vicksburg.	Apalachicola
Oligopygus floridanus Twitchell						
Cassidulus (Rhynchopygus) lyelli (Conrad)				×		
Cassidulus (Rhynchopygus) patelliformis Bouvé						
Cassidulus (Rhynchopygus) depressus Twitchell						
Cassidulus (Pygorhynchus) conradi Conrad						
Cassidulus (Pygorhynchus) georgiensis Twitchell						
Cassidulus (Pygorhynchus) gouldii Bouvé						
Cassidulus (Pygorhynchus) alabamensis Twitchell						
Echinolampas aldrichi Twitchell						
Hemipatagus argutus Clark						
Agassizia conradi (Bouvé)						
Schizaster armiger Clark						
Schizaster floridanus Clark						
Schizaster americana Clark						
Linthia alabamensis Clark						
Macropneustes mortoni (Conrad)						
Eupatagus floridanus Clark						

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NOTE.—A number of contributions have appeared during the progress of this report through the press, the results of which can not be fully incorporated in the following pages, although footnotes concerning some of them have been inserted. Among the more important of these publications are:

PACK, R. W., Notes on *Scutella norrisi* and *Scutaster andersoni:* California Univ. Dept. Geology Bull., vol. 7, No. 13, pp. 299–304, Pl. XV, 1913. Pack furnishes additional information of value regarding the species mentioned.

KEW, W. S. W., Tertiary echinoids of the Carrizo Creek region in the Colorado Desert: California Univ. Dept. Geology Bull., vol. 8, No. 5, pp. 39–60, Pls. I–V, 1914. Kew describes the following forms: *Encope tenuis* n. sp., *Clypeaster deserti* n. sp., *C. carrizoensis* n. sp., *C. bowersi* Weaver, *Hipponoë californica* n. sp., and Cidaris sp.

EOCENE ECHINODERMATA.

Class CRINOIDEA.

Subclass DICYCLICA.

Order FLEXIBILIA.

Suborder PINNATA.

Family ANTEDONIDÆ.

Genus ZENOMETRA A. H. Clark.

ZENOMETRA (?) CONOIDEUS (Emmons).

Microcrinus conoideus Emmons, 1858, Agriculture Eastern Counties: North Carolina Geol. Survey Rept., p. 311, figs. 246, 247.

Microcrinus conoideus Conrad, 1866, Check list, Eocene and Oligocene, p. 31.

Description.—The descriptions and figures of this form by Emmons are very inadequate. Springer, who kindly examined them for the author, says:

> Emmons's figures represent the centro-dorsal of a comatulid, broken away from the radials, preserving the "rosette" filled with matrix, and the "basal rays." The latter indicate noncontiguous basals—a character which removes it from *Atelocrinus*. The regular arrangement of cirrus sockets in columns, combined with the large central cavity of the centrodorsal, places it in the family Antedonidæ, as restricted by Mr. A. H. Clark, and it might belong to a form like his genus Zenometra, recent species of which occur in the Atlantic and Caribbean from the Carolinas to St. Lucia. Without the superior parts of the calyx it is impossible to make closer comparison, and it must remain among the imperfectly known.

No specimens have been secured in recent collecting and no material representing this species has been found in any museum.

Locality.—Craven County, N. C. (Emmons).

Geologic horizon.—Trent marl, middle Eocene.

Collection.—Unknown.

Class STELLEROIDEA.

Subclass ASTEROIDEA.

Order CRYPTOZONIA.

Family ASTERIIDÆ.

Genus ASTERIAS Linné.

ASTERIAS (?) sp.

Asterias Morton, 1834, Synopsis Organic Remains Cretaceous, p. 74.

Description.—Morton says: "I have seen but a few obscure fragments of this genus, from the calcareous strata of South Carolina." It is quite impossible without authentic specimens to determine whether the material in Morton's hands belongs to this genus or not.

Locality.—South Carolina.

Geologic horizon.—Eocene.

Collection.—Unknown.

Class ECHINOIDEA.

Subclass REGULARIA ENDOBRANCHIATA.

Order CIDAROIDEA.

Family CIDARIDÆ.

Genus CIDARIS Leske.

Cidaris mitchelli Emmons.

Plate LV, figures 1a–c.

Cidaris mitchelli Emmons, 1858, Agriculture Eastern Counties: Rept. North Carolina Geol. Survey, p. 305, fig. 237.
Cidaris mitchelli Conrad, 1866, Check list, Eocene and Oligocene, p. 3.
Cidaris mitchelli Heilprin, 1884, Contrib. Tertiary geology, p. 17.
Cidaris mitchelli Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 693.

Determinative characters.—Test large, thick, and of moderate height. Ambulacra rather broad, somewhat undulating with four to six rows of granules between the poriferous avenues. Interambulacra wide with 9 to 10 plates in each row, each plate bearing a single large circular tubercle the areola of which is surrounded by a row of small tubercles. Miliary space covered with numerous thickly radiated granules.

Dimensions.—Diameter 53 millimeters; height 32 millimeters.

Description.—The species is represented by a single specimen, the type described by Emmons, which in many particulars is in an excellent state of preservation. The test is large, thick, and circular in outline. It is of medium height.

The ambulacra are rather broad and somewhat undulating, with four rows of granules between the poriferous avenues toward the apical system and peristome, but with six rows on the ambitus. The pores are oral and connected by deep furrows.

The interambulacra are wide and bear two rows of large circular tubercles, the areolas of which closely approach each other and are covered by a row of small tubercles. The tubercles are round, depressed, and have much elevated and deeply perforated mamelons.

Related forms.—The species is most closely related to *C. carolinensis* but is somewhat lower, the granules on its miliary space are smaller and differently distributed and its tubercles approach each other more closely. Its areolas have a surrounding row of small tubercles which are absent in *C. carolinensis*.

Locality.—Craven County (?), N. C. (Emmons).

Geologic horizon.—Trent marl, middle Eocene.

Collection.—Williams College.

Cidaris carolinensis Emmons.

Plate LV, figures 2a–c.

Cidaris carolinensis Emmons, 1858, Agriculture Eastern Counties: North Carolina Geol. Survey Rept., pp. 305–306, fig. 238.
Cidaris carolinensis Conrad, 1866, Check list, Eocene and Oligocene, p. 31.
Cidaris carolinensis Heilprin, 1884, Contrib. Tertiary geology, p. 17.
Cidaris carolinensis Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 698.

Determinative characters.—Test large, thick, and rather tall. Ambulacra rather broad, somewhat undulating, with four rows of granules between the poriferous avenues. Interambulacra wide, each with two rows of large circular tubercles, 10 to 11 in each row. Miliary space covered with numerous thickly set granules.

Dimensions.—Diameter 60 millimeters; height 35 millimeters.

Description.—The type specimen of Emmons is the only representative of this species that has been available for study. Although somewhat crushed the portions preserved are in an excellent state of preservation. The test is of rather large size, thick, and somewhat taller than in most species of Cidaris.

The ambulacra are rather wide and somewhat undulating, with four rows of granules between the poriferous avenues on the upper and lower surfaces, which become increased to six at the ambitus. The pores are oval in shape.

The interambulacra are wide, each with two rows of large circular tubercles that however leave a wide miliary space on each plate that is thickly set with granules of very uniform size throughout. The tubercles are round and deeply depressed. The boss is smooth and the mamelons deeply perforated.

Related forms.—This species is closely related to *C. mitchelli* but is evidently taller and has larger granules somewhat differently dispersed. Its tubercles are more widely separated than those of *C. mitchelli*, and its areolas lack the surrounding row of small tubercles.

Locality.—Craven County (?), N. C. (Emmons).

Geologic horizon.—Trent marl, middle Eocene.

Collection.—Williams College.

Cidaris pratti Clark, n. sp.

Plate LV, figure 3.

Determinative characters.—Test small, thin, rather high, circular. Ambulacra narrow undulating, two rows of granules between the poriferous avenues; pores nearly round. Interambulacra wide, each with two rows of tubercles; each tubercle round, depressed, with crenulated boss and perforated mamelon and with areolas surrounded by row of small tubercles.

Dimensions.—Diameter 18 (?) millimeters; height 15 (?) millimeters.

Description.—The only specimens available for study consist of fragments of tests, chiefly of detached plates. The test is small and thin, rather high, and apparently circular in outline.

The ambulacra are narrow and undulating. The pores are nearly round. Two rows of small granules occur between the poriferous avenues.

The interambulacra are wide, each with two rows of tubercles which largely occupy the area of the plates. The miliary space is very small and covered with granules. Each tubercle has a depressed areola surrounded by a row of small tubercles. The boss is crenulated and the mamelon perforated.

Related forms.—The species is unique and differs widely from the other Tertiary species. It is more closely related to *C. mitchelli* than to *C. carolinensis*.

Locality.—Wilmington, N. C.

Geologic horizon.—Castle Hayne limestone, upper Eocene or Oligocene.

Collection.—U. S. National Museum (164663).

Cidaris merriami Arnold.

Plate LV, figure 4.

Cidaris merriami Arnold, 1908, U. S. Nat. Mus. Proc., vol. 34, p. 359, Pl. XXXII, fig. 8.
Cidaris merriami Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 696.

Determinative characters.—Test wanting. Spine subcircular in cross section, tapering slightly; surface with 13 or 14 prominent ribs separated by narrow grooves; nodes well defined.

Dimensions.—Longest fragment; length 20 millimeters; maximum diameter 4.5 millimeters.

Description.—Arnold, in his description of this species, says:

> The test of this species is unknown, but the abundance and well marked characteristics of the fragments of the spines has been deemed of enough importance to justify a specific name. Seven specimens have been obtained at the type locality, each showing the characters described above.
>
> Spines subcircular in cross section, as much as 4 millimeters in diameter and probably over 40 millimeters in length, tapering very slightly; surface sculptured by 13 or 14 prominent, narrow, nodose, ridgelike, longitudinal ribs separated by narrow, deeply incised grooves; the nodes are well defined, especially in the younger stages of growth, and are subelliptical in cross section, their longer axis being parallel with the axis of the spine.

H. L. Clark, who examined the specimens for Arnold, says that they

All appear to belong to one species, except possibly one fragment. That piece might *possibly* have come from quite a different species. I am very glad to see this material of *merriami*, for it satisfies me that the species must have been allied to, not identical with, *Tretocidaris perplexa* Clark (Cidaridæ, 1907, p. 205, Pl. VI, figs. 1–2; Pl. VII, figs. 1–4), the only other living littoral cidarid known from north of Panama (other, I mean, than *thouarsii*). So your material shows that the ancestors of both *thouarsii* and *perplexa* lived in the Tertiary in California.

Locality.—Santa Cruz quadrangle, San Mateo County, locality No. 25, ridge between headwaters of San Lorenzo River and Pescadero Creek, Cal.

Geologic horizon.—Eocene, possible equivalent of Martinez formation.

Collection.—U. S. National Museum (165, 438).

Cidaris mœreus De Gregorio.

Cidaris mœreus De Gregorio, 1890, Mon. faune éocénique Alabama, p. 252, Pl. XLIII, figs. 22–23
Cidaris mœreus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Description.—No specimens of this species were available for study. The type form described by de Gregorio evidently came with other materials from the Claiborne in Alabama. The author describes the species as follows: "Aculeus subcylindraceus, oblongus, tuberculis erectis notatis confertis majoribus et minoribus irregulariter dispositis ornatus."

Locality.—Near Claiborne, Ala.

Geologic horizon.—Claiborne group, middle Eocene.

Collection.—De Gregorio.

Cidaris modestus De Gregorio.

Cidaris modestus De Gregorio, 1890, Mon. faune éocénique Alabama, p. 253, Pl. XLIII, fig. 26.
Cidaris modestus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Description.—No specimens of this species were available for study. The type form described by De Gregorio evidently came with other materials from the Claiborne in Alabama. The author describes the species as follows: "Aculeus augustus, conoideo-cylindraceus, costulis longitudinalibus ornatus; costis crenulatis, granulo-squamosis; granulis subimbricatis."

Locality.—Near Claiborne, Ala.

Geologic horizon.—Claiborne group, middle Eocene.

Collection.—De Gregorio.

Cidaris ordinatus De Gregorio.

Cidaris ordinatus De Gregorio, 1890, Mon. faune éocénique Alabama, p. 352, Pl. XLIV, fig. 1.
Cidaris ordinatus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Description.—No specimens of the species were available for study. The type form described by De Gregorio evidently came with other materials from the Claiborne group near Claiborne, Ala. The author describes the species as follows: "Aculeus subcylindraceus; tuberculis erectis, raris, subæqualibus, quincuncim atque spiraliter regulariter dispositis."

Locality.—Near Claiborne, Ala.

Geologic horizon.—Claiborne group, middle Eocene.

Collection.—De Gregorio.

Cidaris perdubius De Gregorio.

Cidaris perdubius De Gregorio, 1890, Mon. faune éocénique Alabama, p. 253, Pl. XLIV, fig. 2.
Cidaris perdubius Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Description.—No specimens of this species were available for study. The type form described by De Gregorio evidently came with other materials from the Claiborne in Alabama. The author describes the species as follows: "Aculeus cylindraceus potius augustus, tenu tuberculatus; tuberculis densis, parvis, in series longitudinales recte dispositis."

Locality.—Near Claiborne, Ala.

Geologic horizon.—Claiborne group, middle Eocene.

Collection.—De Gregorio.

Cidaris blandis De Gregorio.

Cidaris blandis De Gregorio, 1890, Mon. faune éocénique Alabama, p. 253, Pl. XLIV, fig. 4.
Cidaris blandis Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Description.—No specimens of this species were available for study. The type form described by De Gregorio evidently came with other materials from the Claiborne group near Claiborne, Ala. The author describes the species as follows: "Aculeus augusta, conoideo-cylindraceus, costulis longitudinalibus ornatus; costis crenulatis, granulo-squamosis; granulis subimbricatis."

Locality.—Near Claiborne, Ala.

Geologic horizon.—Claiborne group, middle Eocene.

Collection.—De Gregorio.

Cidaris alabamensis Morton.

Cidaris alabamensis Morton, 1846, Acad. Nat. Sci. Philadelphia Proc., vol. 3, p. 51.
(?) Cidaris sp. Aldrich, 1886, Alabama Geol. Survey Bull. 1, p. 43.
Cidaris alabamensis Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Description.—No material has been obtained that can be regarded as belonging to this species, which Morton very inadequately describes and which he does not figure. Morton in his description says that this species is "Compressed, pentagonal, the angles rounded so as to form a 10-sided figure. Ten rows of tubercles, with 9 or 10 in each row. Ambulacra arranged in five pairs, with delicate, slightly oblique fissures separated by a double elevated line. Surface between the tubercles and ambulacra finely granulated." Morton states that the specimen described was found in the "Eocene strata of Washington County, Ala.," but if it was derived from the St. Stephens limestone, as seems probable, it may be Oligocene, for the upper beds are of that age.

Locality.—Washington County, Ala. (Morton).

Geologic horizon.—St. Stephens (?) limestone, Eocene (?).

Collection.—Unknown.

Cidaris sp.

Cidaris sp. De Gregorio, 1890, Mon. faune éocénique Alabama, p. 252.

Description.—The material representing this species is referred to by De Gregorio in these words: "Auctor nullam descriptionem hujus specei dat." No figure is given.

Locality.—Near Claiborne, Ala.

Geologic horizon.—Claiborne group, middle Eocene.

Collection.—De Gregorio.

Subclass REGULARIA ECTOBRANCHIATA.

Order DIADEMOIDEA.

Suborder ARBACINA.

Family ARBACHIDÆ.

Genus CŒLOPLEURUS Agassiz.

CŒLOPLEURUS INFULATUS (Morton).

Plate LVI, figures 1a–i.

Echinus infulatus Morton, 1833, Am. Jour. Sci., 1st ser., vol. 24, p. 131, Pl. X, fig. 7.
Echinus infulatus Morton, 1834, Synopsis Organic Remains, p. 75, Pl. X, fig. 7.
Echinus infulatus Morton, 1842, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 8, p. 217.
Echinus infulatus Bronn, 1848, Index palæontologicus, vol. 1, p. 450; vol. 2, p. 187.
Echino-cidaris infulatus Ravenel, 1850, Am. Assoc. Adv. Sci. Proc., vol. 3, p. 160.
(?) *Arbacia* (?) sp. Bouvé, 1851, Boston Soc. Nat. Hist. Proc., vol. 4, p. 3.
Cœlopleurus infulatus Desor, 1858, Synopsis des échinides fossiles, p. 98.
Echinus infulatus Gabb, 1859, Cat. Invertebrate Fossils Cretaceous, p. 19.
Cœlopleurus depressus Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., vol. 23, p. 74.
Cœlopleurus infulatus Conrad, 1866, Check list, Eocene and Oligocene, p. 22.
Cœlopleurus depressus Conrad, 1866, Check list, Eocene and Oligocene, p. 22.
Cœlopleurus (*Echinus*) *inflatus* A. Agassiz, 1874, Revision of the Echini, p. 751.
Echinus infulatus ? Aldrich, 1886, Alabama Geol. Survey Bull. 1, p. 43.
Cœlopleurus infulatus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Echinus infulatus Boyle, 1893, U. S. Geol. Survey Bull. 102, p. 118.
Cœlopleurus infulatus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 698.
Cœlopleurus depressus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 698.

Determinative characters.—Test moderate, depressed. Ambulacra narrow, projecting on upper surface, with two rows of tubercles extending from the peristome to the apical system, plates compound except near apex; poriferous avenues narrow; pore pairs uniserial, in arcs. Interambulacra broad, each with four rows of primary tubercles extending from the peristome to slightly above the ambitus beyond which the inner rows disappear. Apical system large, the genital plates in contact. Peristome with small branchial incisions. Periproct large subpentagonal.

Dimensions.—Diameter 19.5 millimeters; height 10 millimeters.

Description.—This very characteristic species is represented by a single specimen from the Santee marl member of the McBean formation of South Carolina. The test is of moderate size, depressed and subpentagonal in outline.

The ambulacra are narrow and project above the general level of the test. Each ambulacrum has two rows of primary tubercles that extend from the peristome nearly to the apex. The tubercles are imperforate and noncrenulate. The plates are compound except near the apex and consist of one primary and two demiplates. The poriferous avenues are narrow, and the pore pairs which are uniserial are in arcs.

The interambulacra are broad, each area being covered with four rows of primary tubercles which extend from the peristome to a little above the ambitus, beyond which the two central rows disappear, and the outside rows gradually decline in size to very small tubercles or even into granules. The large bare median area produces a broad depression on the upper surface.

The apical system is large, the genital plates coming into contact and separating the small oculars.

The peristome is large with small branchial incisions. The periproct is large and subpentagonal in outline.

Locality.—South Carolina (Morton).

Geologic horizon.—Santee marl member of McBean formation, of Claiborne group, middle Eocene.

Collection.—Academy of Natural Sciences of Philadelphia (1076).

Suborder DIADEMINA.

Family CYPHOSOMATIDÆ.

Genus ORTHECHINUS Gauthier.

ORTHECHINUS PRETIOSUS Clark, n. sp.

Plate LVI, figures 2 a-b.

Determinative characters.—Test small, depressed, circular. Ambulacra wide, with two rows of low primary tubercles, crenulate and imperforate; poriferous avenues straight, pore pairs uniserial, with three pairs to each plate. Interambulacra with two rows of primary tubercles similar to those of ambulacra and with additional smaller tubercles and granules. Apical system large. Periproct large.

Dimensions.—Diameter 20 millimeters; height 8 millimeters.

Description.—A single crushed specimen of this species has been found. The test is small depressed, and circular in ambital outline. The ambulacra are wide with two rows of crenulate and imperforate small primary tubercles, which are somewhat indistinct on account of their relatively small, low mamelons and small areolas. Smaller tubercles and granules are also found. The poriferous avenues are straight, the pore pairs uniserial with three pairs to each compound plate.

The interambulacra have two rows of primary tubercles similar to the ambulacra together with smaller tubercles. The miliary space is covered with irregularly dispersed granules.

The apical system is large, pentagonal in outline, and with large genital plates. The periproct is large.

Locality.—Dead Level, Choctaw County, Ala.

Geologic horizon.—St. Stephens limestone (lower portion), upper Eocene.

Collection.—U. S. National Museum (146455).

Suborder ECHININA.

Family TRIPLECHINIDÆ.

Genus ECHINUS Linné.

ECHINUS EXERCEUS De Gregorio.

? Echinus sp. Aldrich, 1886, Alabama Geol. Survey Bull. 1, p. 49.
Echinus exerceus De Gregorio, 1890, Alabama Mon. faune éocénique, p. 252, Pl. XLIV, fig. 3.
Echinus exerceus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Description.—No material representing this species was available for study. De Gregorio gives the following description: "Aculeus exilis, oblongus, sub lente minutissime eleganter punctulatus reticulatusque, inferne ad basim turgidus."

Locality.—Near Claiborne, Ala. (De Gregorio).

Geologic horizon.—Claiborne group, middle Eocene.

Collection.—De Gregorio.

ECHINUS (?) sp.

Plate LVI, figure 3.

Diadematoid spines, Clark and Martin, 1901, Maryland Geol. Survey, Eocene, p. 232, Pl. LXI, fig. 2.

Description.—Several small, thin echinoid spines, the generic relations of which can not be with certainty determined, have been found in the Eocene deposits of Maryland and Virginia. They are doubtfully referred to Echinus.

Localities.—Near South River and Severn River, Md.; Potomac Creek, Va.

Geologic horizon.—Aquia formation, lower Eocene.

Collection.—Johns Hopkins University (T 2000).

Subclass IRREGULARIA.

Order GNATHOSTOMATA.

Suborder CLYPEASTRINA.

Family FIBULARIIDÆ.

Genus ECHINOCYAMUS Phelsum.

Echinocyamus parvus Emmons.

Echinocyamus parvus Emmons, 1858, Agriculture Eastern Counties: North Carolina Geol. Survey Rept., p. 307, fig. 244.
Echinocyamus parvus Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 31.
Echinocyamus parvus Heilprin, 1884, Contrib. Tertiary Geology U. S., p. 17.
Echinocyamus parvus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 698.

Description and determinative characters.—The location of Emmons's type of this little echinoid is unknown, and the writer has been unable to find any specimen similar to it in the North Carolina material studied. The description of Emmons is therefore quoted in full, as follows:

> Test small, oval, with rounded sides, avenues dorsal; mouth subcentral, rounded, large, with a crenulated margin; vent between the mouth and hinder margin; genital pores apparently four. The mouth is large in proportion to the size of the body and the vent is situated halfway between the mouth and the margin.

Dimensions.—Emmons's figure, which he states is natural size, is 5 millimeters in length and 3 millimeters in width.

Related forms.—*E. parvus* is closely allied to *E. huxleyanus*. The latter apparently differs, however, in being more pointed anteriorly and in having the periproct near the posterior margin. *E. parvus* is also closely related to *E. vaughani* and *E. texanus*, which are to be distinguished by having the periproct nearer the peristome.

Locality.—Craven County, N. C. (Emmons).

Geologic horizon.—Eocene (Emmons). Very probably from the Trent marl.

Echinocyamus huxleyanus Meyer.

Plate LVII, figures 1a–d.

Echinocyamus huxleyanus Meyer, 1886, Alabama Geol. Survey Bull. 1, p. 85, Pl. III, fig. 23.
Echinocyamus huxleyanus De Gregorio, 1890, Mon. faune éocénique Alabama, p. 251, Pl. XLIII, fig. 15.
Echinocyamus huxleyanus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Determinative characters.—Test thin-walled and fragile, very small, flattened egg-shaped, anterior end pointed. Upper surface low, convex; under surface concave around peristome. Apical system excentric anteriorly, with four large genital pores. Petals rudimentary, open at ends; pores not conjugated. Peristome central, relatively large. Periproct small, about one-fourth the distance from margin to peristome. Tubercles relatively large.

Dimensions.—Length 3 to 5 millimeters; width 2 to 3 millimeters; height 1 to 2 millimeters.

Description.—This little Echinocyamus is found in some abundance in the sands of the Claiborne group in Alabama. The test is notably thin-walled and fragile, in strong contrast with the other American representatives of the genus. In marginal outline it is subelliptical to elongate subovate and in general form subellipsoidal to flattened egg-shaped; the anterior end being more or less pointed, and the height being about half or less than half of the width. The upper surface is low and gently convex; the lower surface flattened, slightly concave close to the peristome.

The ambulacral petals are rudimentary, extending two-thirds or more of the way to the margin, open at the ends; poriferous zones nearly straight, pores round, pairs not conjugated. The apical system is excentric anteriorly, with four large genital pores set close together, the anterior pair being only slightly nearer together than the posterior pair.

The surface of the test is covered with numerous small but rather conspicuous tubercles set in relatively large scrobicules.

The peristome is central, relatively large, circular. The periproct is small, about one-half the diameter of the peristome, situated near the margin, being about one-fourth of the distance from the margin to the peristome.

Related forms.—*E. huxleyanus* is closely related to *E. parvus*. In fact, it is quite possible that with the discovery of some good specimens of Emmons's form *E. huxleyanus* may be found to be identical and be reduced to a synonym. It appears to differ from *E. parvus*, however, in having its periproct nearer the margin and in being more pointed anteriorly. It also resembles both *E. texanus* and *E. vaughani*, but differs from them in having thinner walls, in being less elevated, and in not having its periproct near the peristome.

Locality.—Claiborne, Ala.

Geologic horizon.—Gosport sand, Claiborne group, middle Eocene.

Collections.—U. S. National Museum (figured form); Johns Hopkins University (T 2006).

Echinocyamus texanus Twitchell, n. sp.

Plate LVII, figures 2a–d.

Determinative characters.—Test very small, ellipsoidal, oval in marginal outline. Upper surface elevated, somewhat flattened in the center; lower surface flattened around the nearly flush peristome. Apical system with four medium-sized genital pores; madreporite tumid. Petals long, the anterior three nearly reaching the margin, wide open at ends. Peristome relatively large, central; periproct very small, close to peristome.

Dimensions.—Length 5 millimeters; width 4 millimeters; height 2.5 millimeters.

Description.—Only a single specimen of this new Echinocyamus has been discovered. It was found by Mr. T. H. Aldrich of Birmingham, Ala., who reports that it was found in the "Lower Claiborne" deposits of Lee County, Tex. The test is thick-walled, very small (it being one of the smallest of American echinoderms), regularly oval in marginal outline, and ellipsoidal in general form. The upper surface is elevated, somewhat flattened centrally; the lower surface flattened near the nearly flush peristome and the periproct.

The ambulacral petals are rather well defined, relatively long, all of about equal length, the anterior three extending nearly to the margin as seen from above. The poriferous zones diverge in almost straight lines to the ends where they are wide apart; they consist of small round pores in pairs which are apparently not conjugated.

The apical system is subcentral or very slightly excentric anteriorly, coincident with the apex, with four moderate-sized genital pores set near together, the anterior pair but slightly nearer together than the posterior pair. A small, swollen, button-shaped madreporite just reaches to the genital pores.

The peristome is relatively large, central, nearly flush with the lower surface; periproct very small, about one-third of the diameter of the peristome, and is situated at a distance from the peristome equal to its own diameter.

Related forms.—*E. texanus* is most closely related to *E. vaughani*, but is easily distinguished from it by its less egg-shaped form, smaller size, less pointed anterior end, and less difference between its longitudinal and transverse diameters. *E. texanus* also resembles *E. parvus* and *E. huxleyanus* but differs from both in having its periproct near the peristome. It also differs from *E. huxleyanus* in being less fragile, less depressed, and less pointed anteriorly.

Locality.—Lee County, Tex.

Geologic horizon.—Lower part of Claiborne group, middle Eocene.

Collection.—Johns Hopkins University (T 2002).

Genus SISMONDIA Desor.

Sismondia (?) plana Conrad.

Plate LVII, figures 4a–d.

Sismondia plana Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 75.
Mortonia (Periarchus) plana Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 21.
Sismondia plana Cotteau, 1891, Paléontologie française, Échinides éocènes, vol. 2, p. 299.
Monostychia plana Gregory, 1891, Geol. Soc. America Bull., vol. 3, p. 108.
Periarchus (?) *plana* Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 699.

Determinative characters.—Test very small, very thin, subovate to subcircular in marginal outline, rounded to somewhat pointed anteriorly and posteriorly. Upper surface very low, slightly tumid centrally; apex and apical system more or less anteriorly excentric; lower surface flat; margin very thin. Ambulacral petals subelliptical, extending halfway to margin, nearly closing at ends. Peristome slightly excentric anteriorly, small, circular; ambulacral grooves well defined and simple halfway to the margin, then obscure but apparently not branching. Periproct very small, elliptical, about two-fifths the way from margin to peristome.

Dimensions.—Length 17 millimeters; width 15 millimeters; height 2 millimeters.

Description.—The test of this species is very small, rarely exceeding one-half an inch in diameter, very thin throughout, subovate to subcircular in marginal outline, rounded to somewhat pointed anteriorly and posteriorly, broadest back of the middle. The upper surface is very low, slightly tumid centrally; the apex usually excentric anteriorly, sometimes subcentral; the lower surface flat; the margin very thin.

The ambulacral petals are well defined but small, extending only halfway to the margin, broadly lanceolate to subelliptical in outline, nearly closing at the ends; several pairs of pores extend beyond the ends of the petals. The poriferous zones are relatively narrow, inner row of pores round, outer row oval, pairs of pores conjugated; interporiferous areas rather narrow, not much wider than the poriferous zones.

The apical system is subcentral or excentric anteriorly, coincident with the apex. The details could not be clearly made out on the specimens.

The tuberculation is inconspicuous, the whole test being covered with small tubercles, in shallow scrobicules, set closely together.

The peristome is subcentral or slightly excentric anteriorly, small, circular. The ambulacral grooves extend as well defined simple lines from the peristome halfway to the margin, beyond which point they become obscure; but do not appear to branch.

The periproct is very small, elliptical, the longest diameter being longitudinal, located about two-fifths of the way from the margin to the peristome.

Related forms.—*Scutella* (?) *conradi* is closely related to *Sismondia* (?) *plana* but differs from it in having its posterior border truncated and notched at the middle and opposite the posterior petals, and its periproct nearer the posterior border.

Locality.—The type came from South Carolina. (No more definite locality can be given.) Some specimens came from near Charleston, S. C.

Geologic horizon.—Eocene.

Collection.—Academy of Natural Sciences of Philadelphia (1080).

Genus FIBULARIA Lamarck.

Fibularia meridionalis (Meyer).

Plate LVII, figures 3a–d.

Echinocyamus meridionalis Meyer, 1887, Fauna Alttertiärs Mississippi und Alabama, p. 12, Pl. II, figs. 21, 21a.
Echinocyamus meridionalis De Gregorio, 1890, Mon. faune éocénique Alabama, p. 251, Pl. XLIII, fig. 14.
Echinocyamus meridionalis Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Determinative characters.—Test thin walled and fragile, very small, discoidal, broadly oval to subcircular in marginal outline. Upper surface very low, flat or nearly so; sides rounded; lower surface slightly concave. Apical system central or subcentral; petals rudimentary.

inconspicuous. Peristome central, unusually large, much larger than periproct, circular, with crenulated margin. Periproct very small, nearer to posterior margin than to peristome.

Dimensions.—Length 2 to 4 millimeters; width 1.5 to 3 millimeters; height 0.5 to 1 millimeter.

Description.—This little echinoid occurs in comparative abundance in association with *Echinocyamus huxleyanus* in the Gosport sand at Claiborne, Ala., and elsewhere. The test is thin walled and fragile, very small, rarely reaching a quarter of an inch in length, discoidal in general form, broadly oval to subcircular in marginal outline. The upper surface is very low, rarely over a millimeter in height, flat or faintly convex; the sides rounded; the lower surface nearly flat, or slightly concave. In a few specimens several faint radiating creases can be distinguished on the lower side.

The ambulacral petals are decidedly rudimentary, so inconspicuous as to be difficult to discern on even good specimens; short, extending less than halfway to the margin, the poriferous zones nearly parallel and composed of very small pores in pairs which are not conjugated.

The apical system is central or subcentral, usually broken out. The genital pores are very small and can rarely be made out on the specimens.

The whole surface of the test is covered with small tubercles, set in relatively large scrobicules.

The peristome is central and unusually large in proportion to the size of the test, its diameter being 4 or 5 times that of the periproct. The periproct is very small, circular, and situated from one-fourth to one-third of the way from the posterior margin to the peristome.

Related forms.—*F. meridionalis* is not closely related to any other American species. In its fragility, size, and superficial characteristics it resembles *E. huxleyanus*, but differs in having a more rudimentary apical system and ambulacral petals and in its very low, subcircular, discoidal form.

Localities.—Claiborne, Ala., and Jackson, Miss.

Geologic horizon.—Gosport sand of Claiborne group, middle Eocene.

Collections.—Johns Hopkins University (T 2005); U. S. National Museum.

Family LAGANIDÆ.

Genus LAGANUM Blainville.

Laganum (?) crustuloides (Morton).

Plate LVII, figures 5a–d, 6a–d.

Scutella crustuloides Morton, 1833, Am. Jour. Sci., 1st ser., vol. 24, p. 131, Pl. X, fig. 8.
Scutella crustuloides Morton, 1834, Synopsis Organic Remains Cretaceous, p. 77, Pl. XV, fig. 10.
Scutella crustuloides Morton, 1842, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 8, p. 217.
Scutella crustuloides Bronn, 1848, Index Palæontologicus, vol. 1, p. 1126; vol. 2, p. 196.
Scutella crustuloides Ravenel, 1848, Echinidæ, recent and fossil, of South Carolina, p. 2.
Scutella crustuloides Ravenel, 1850, Am. Assoc. Adv. Sci. Proc., vol. 3, p. 160.
Sismondia crustuloides Desor, 1858, Synopsis des échinides, p. 227.
Scutella crustuloides Gabb, 1859, Cat. Invert. Fossils Cretaceous, p. 19.
Scutella crustuloides Dujardin and Hupé, 1862, Histoire nat. zoophytes échinodermes, p. 559.
Sismondia crustuloides Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., pp. 74–75.
Sismondia crustuloides Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 21.
Scutella crustuloides De Gregorio, 1890, Mon. faune éocénique Alabama, p. 251, Pl. XLIII, figs. 24–25 (reprod. from Morton).
Sismondia crustuloides Cotteau, 1891, Paléontologie française, Échinides éocènes, vol. 2, p. 300.
Scutella crustuloides Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Scutella crustuloides Boyle, 1893, U. S. Geol. Survey Bull. 102, p. 262.
Periarchus (?) *crustuloides* Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 699.

Determinative characters.—Test small, subpentagonal, suboval or subovate in marginal outline. Upper surface low, tumid centrally; margin very thick, submarginal area flat or nearly so, about the same thickness as the margin. Lower surface concave. Apex and apical system slightly excentric anteriorly. Ambulacral petals lanceolate, pointed and closed at the ends,

extending two-thirds the way to the margin; poriferous zones much narrower than interporiferous areas. Peristome small, subpentagonal, slightly excentric anteriorly; ambulacral grooves simple, straight, inconspicuous. Periproct small, subcircular, from one-fourth to one-third the way from margin to peristome.

Dimensions.—Specimen A: Length 21 millimeters; width 26 millimeters; height 5 millimeters. Specimen B: Length 31 millimeters; width 26 millimeters; height 6 millimeters.

Description.—This little echinoid was one of the first reported from American deposits, having been described and figured by Morton as early as 1833. It is relatively somewhat abundant in the Eocene deposits and has been found in South Carolina, Georgia, and Alabama. The test is small, ranging from three-quarters of an inch to 1¼ inches in length. In marginal outline it is rather variable, being subpentagonal in most specimens but suboval or subovate in some. The whole form is greatly depressed, the upper surface tumid centrally, the tumid area involving the larger part or all of the ambulacral petals; the margin is rounded and notably thickened all around, though slightly less so at the middle of the posterior end than elsewhere, the submarginal area flat or nearly so, as thick as or more or less thick than the margin. The under surface is decidedly concave, the concavity reaching nearly to the margin. The apex is slightly excentric anteriorly at the summit of the tumid area.

The ambulacral petals are lanceolate or elongate subelliptical, pointed and practically closed at the distal ends; the anterior pair slightly shorter than the other three, all of them extending about two-thirds the way to the margin. The poriferous zones are very narrow, much narrower than the interporiferous areas, sometimes irregular, the inner ends poorly defined, inner row of pores round, outer row slitlike, pairs of pores conjugated. The whole surface of the test, including the interporiferous areas and the apical region is covered with rather conspicuous small tubercles set in deep scrobicules which are larger on the lower surface.

The apical system is central or slightly excentric anteriorly at the summit of the tumid area. There are four large genital pores, the anterior pair being set closer together than the posterior pair. The poriferous zones rarely if ever can be seen to come together at the proximal ends, and the perforations of the radial plates, if they exist, can not be discerned.

The peristome is small, subpentagonal, slightly excentric anteriorly; the ambulacral grooves are never very distinct on even well preserved specimens. They appear to be straight, simple, faint lines from peristome to near the margin, distinguished more by finer tuberculation than by the existence of a distinct groove.

The periproct is small, about one-third the diameter of the peristome, subcircular, situated from one-fourth to one-third the way from the margin to the peristome.

Related forms.—Of American forms *L.* (?) *crustuloides* is most closely related to *L. johnsoni* which differs chiefly in being higher and having a thicker margin. *L.* (?) *crustuloides* is also closely related to *L. floridanum* which differs in having a smaller petaloidal area, a more regularly oval marginal outline, a concave ring around the ends of the petals and a flat lower surface. *Scutella* (?) *conradi* also resembles the present species but differs in having its margin thin and posteriorly truncated and notched. *L. archerensis* and *L. dalli* both differ in having flat lower surfaces and the apical region but little if any higher than their thick margins.

Of foreign forms the present species is allied to *Laganum reflexum* from the Tertiary of Blaye, France, which, however, is thinner posteriorly. *Sismondia marginalis* (Des Moulins) Desor from the middle Eocene of France also resembles the present form but differs in having petals which are longer and more open at the end.

Localities.—South Carolina, probably near Charleston; near Bainbridge, Ga.; Dothan, Ala.

Geologic horizon.—Jackson formation, (probably) upper Eocene; Vicksburg formation, lower Oligocene.

Collections.—Boston Society of Natural History (8802a, A); U. S. National Museum (164, 744, B).

Family SCUTELLIDÆ.

Genus SCUTELLA Lamarck.

Scutella Lamarck, 1816 (pars), Anim. sans vert., vol. 3, p. 7.
Scutella Lamarck, 1840, Anim. sans vert., 2d ed., vol. 3, pp. 275–277.
Scutella Agassiz, 1841, Mon. d'échinodermes, vol. 2, Des scutelles, p. 75.
Echinarachnius Gray, non Leske, 1825 (pars), Ann. Phil. for 1825, p. 428.
Echinarachnius Agassiz, 1872 (pars), Revision of the Echini, p. 107.

The genus Scutella as here used includes the greatly depressed Scutellidæ without lunules or digitations; with central or subcentral apical system; homogeneous or slightly differentiated plates; ambulacral furrows bifurcating; periproct marginal, inframarginal, or actinal, but less than two-fifths of the way from the margin; and four or five genital pores.

Some of the forms included here are by certain authors placed under Echinarachnius Leske. This practice has not been followed by the writer because apparently Echinarachnius, being founded in 1778 on *Echinus placenta* Linné, should replace the pre-Linnean name Arachnoides Klein with which *placenta* was first associated by L. Agassiz in 1841, and because, even if this correction is made, the writer also questions the giving of separate generic rank to the forms with a strictly marginal periproct.

Genus SCUTELLA Lamarck.

Scutella mississippiensis Twitchell, n. sp.

Plate LIX, figures 1a–f, 2.

Determinative characters.—Test variable in size; subcircular to subtriangular in marginal outline, broader than long, broadest posteriorly; the whole form greatly depressed, being thin and nearly flat around a narrow marginal area within which it rises very gradually and gently to the low, central apex; margin thin, with a small notch in the middle of the posterior edge; under surface flat. Ambulacral petals elliptical, extending about half way to the margin. Apical system central. Peristome small, circular; ambulacral furrows simple and straight for two-thirds or more of the way to the margin, then apparently forking symmetrically. Periproct very small, circular, almost at the ambitus though slightly inframarginal, at the edge of the notch in the middle of the posterior margin.

Dimensions.—Specimen A: Length 50 millimeters; width 52.5 millimeters; height 6 millimeters. Specimen B: Length 52.5 millimeters; width 76 millimeters; height 8 millimeters.

Description.—This new Scutella is one of the most abundant in the American Cenozoic deposits. The writer has had opportunity to examine several hundred specimens. Nearly all of these were from the Eocene deposits of Mississippi, hence the specific name. The test is variable in size, ranging from less than $\frac{1}{2}$ inch to over 3 inches in diameter and from less than $\frac{1}{8}$ to nearly $\frac{1}{2}$ inch in height. The marginal outline is also quite variable, ranging from circular to subcircular in the younger forms to subtriangular and even transversely elliptical in the larger forms. The whole form is much depressed, being thin and nearly flat around a narrow marginal area, although slightly more so posteriorly than elsewhere, from which it rises gradually and gently to the low, central apex. The margin is thin and faintly undulating, with a small notch in the middle of the posterior edge; the under surface is flat except around the peristome, where it is slightly concave. The apex is central or subcentral, at the summit of the broad central tumid area.

The ambulacral areas are narrow in the petaloid region but wide in the marginal region where they are wider than the interambulacral areas. The dorsal portions of the ambulacra are petaloid. The petals are subequal in length, the odd petal slightly longer and narrower than the rest; elliptical in form, slightly open at the ends and extend about half way to the margin. The poriferous zones are rather wide, about equal to the interporiferous areas, though

varying somewhat both among the petals on a single specimen or on different specimens, being slightly wider, equal to, or slightly narrower than the interporiferous areas; the inner row of pores oval, outer row slitlike, pairs of pores conjugated. A few pairs of pores occur beyond the ends of the petals.

The interambulacral areas are large though somewhat smaller both between the petals and at the margin than the ambulacral areas. The whole surface of the test is covered with small uniform tubercles which are slightly larger on the under side.

The apical system is subcentral, at the summit of the central tumid area. The madreporite is relatively large, occupying the larger part of the area covered by the system, and flush with the surface. There are five genital pores near the edge of the madreporite. One specimen studied possessed the abnormal feature of a double posterior genital pore. There are five small radial plates, each perforated by a minute pore.

The peristome is very small, not over double the size of the periproct, circular, central or slightly excentric posteriorly; the ambulacral furrows simple and straight for two-thirds or more of the distance from peristome to margin, then apparently forking symmetrically, each pair of branches continuing almost to the margin. The under side is revealed on few specimens, and on few can the furrows be made out.

The periproct is very small, circular, almost at the ambitus though slightly inframarginal, situated at the under and inner edge of the notch in the middle of the posterior margin.

Related forms.—*S. mississippiensis* does not appear to be closely related to any other American form. It resembles *Periarchus lyelli* in general appearance, and specimens have doubtless been erroneously labeled *S. lyelli* in some collections; *S. mississippiensis*, however, is readily distinguished by its submarginal periproct, greater width, the notch in its posterior edge, and the fact that its tumid central area involves nearly the whole upper surface. It bears an interesting resemblance to the recent species *Scutella parma*, but differs from it in having less widely open petals, much narrower interporiferous areas, a less circular and more anteriorly pointed form, and in not having its periproct exactly marginal or at the ambitus.

Of foreign forms *S. patagonensis* (Desor) Ortman, especially the "alate" form described by Ortman and formerly known as *Echinarachnius juliensis* Desor from the Neocene of Patagonia, appears to be most closely related to *S. mississippiensis*. It is very similar in marginal outline, location of periproct, etc., but differs in having a less central apical system, longer petals, narrower interambulacral areas and in having its ambulacral furrows beginning simply and then forking in symmetrical curving branches almost immediately. *S. subtetragona* De Grateloup and *S. striatula* M. de Serres, both from the upper Eocene of France, also present certain points of identity with *S. mississippiensis*. Each, however, differs from the American form in having four genital pores instead of five and in having the ambulacral furrows fork near the peristome.

Localities.—Cemetery Branch (type), Radiate Banks, Spillman's Clam bed and other localities in and around Enterprise, Clarke County, Miss.; San Augustin, and 1 mile southwest of Palestine, Tex.

Geologic horizon.—Claiborne group, middle Eocene. In Mississippi, at the base of the Lisbon marl. In Texas, in the marine substage of the Claiborne.

Collections.—U. S. National Museum (137655, A; 137655a, B); Wagner Free Institute of Science.

SCUTELLA TUOMEYI Twitchell, n. sp.

Plate LX, figures 1a–d.

Determinative characters.—Test medium in size, subovate in marginal outline, somewhat pointed anteriorly and truncated posteriorly; the whole form greatly depressed, being thin and nearly flat around a narrow marginal area, and only slightly tumid within the petaloidal area; under surface flat. Ambulacral petals narrowly elliptical, the posterior pair extending about half, the others decidedly more than half way to the margin. Apex and apical system central, at the summit of the tumid area. Peristome small, circular; ambulacral furrows simple and

straight for about half the distance to the margin. Periproct very small, subcircular, about one-fourth the way from the posterior margin to the peristome.

Dimensions.—Length 40.5 millimeters; width 39 millimeters; height 5 millimeters.

Description.—This new species is rare, only a single specimen having yet been discovered. As this specimen was found in South Carolina, the form is named in honor of that distinguished worker upon the geology and paleontology of South Carolina, Mr. M. Tuomey. The test is medium in size. In marginal outline it is subovate, broadest posteriorly, narrowing until somewhat pointed anteriorly, truncated along the middle of the posterior border. The whole form is greatly depressed, being quite flat all around the area outside the ambulacral petals, and within the petaloidal area rising only slightly to form a very low broad mound. The margin of the test is thin, with two shallow notches opposite the ends of the posterior petals. The flattened marginal area, from the ends of the petals to the edge, is thin and rather narrow, especially anteriorly, where it is decidedly less wide than the petals are long, while posteriorly the width is about equal to the length of the petals. The under surface is flat or slightly concave from edge to edge. The apex is central or subcentral, at the summit of the tumid area.

The ambulacral areas are narrow in the petaloid region, but wide at the margin, where they are wider than the interambulacral areas. The dorsal portions are petaloid. The petals are of medium size, subequal in length, narrowly elliptical in form, slightly open at the ends; the posterior pair extending about half, the others decidedly more than half, the way to the margin. The poriferous zones are rather wide, almost as wide as the interporiferous areas; inner row of pores oval, the outer slitlike; the pairs of pores conjugated. A few pairs of pores extend beyond the ends of the petals.

The interambulacral areas are rather wide between the petals, wider than the ambulacral areas; of nearly uniform width to the margin where somewhat narrower than the ambulacral areas; composed of large polygonal plates. The whole surface of the test is covered with small uniform tubercles, which are slightly larger on the under side.

The apical system is central or subcentral; coincident with the apex. The details are indistinct upon the specimen; but the madreporite is relatively large, flush with the surface, with five genital pores near its edge.

The peristome is small, circular or subcircular, subcentral; the ambulacral furrows apparently simple and straight for about half the distance to the margin, where they probably fork symmetrically though they do not show well on the only specimen found.

The periproct is very small, about half the diameter of the peristome, subcircular, approaching an inframarginal position, being situated on the under surface about one-fourth the way from the posterior margin to the peristome.

Related forms.—This species is very similar to some specimens of *Periarchus lyelli,* but differs from it in being more pointed anteriorly, in being truncated posteriorly, and in having its periproct nearer to its posterior border. *S. conradi* resembles *S. tuomeyi,* but can be separated by its smaller size, subquadrate posterior end, emarginate posterior border, and nearer approach of periproct to posterior border. *S. tuomeyi* also resembles *S. mississippiensis* in general appearance, but the latter is readily distinguished by the submarginal location of its periproct. There do not appear to be any foreign forms which are closely related.

Locality.—Fourteen miles south of Fort Motte station, Orangeburg County, S. C.

Geologic horizon.—Eocene, probably from the McBean formation of the Claiborne group, middle Eocene. The specimen occurred in a greensand matrix.

Collection.—U. S. National Museum (137970).

SCUTELLA (?) CONRADI (Cotteau).

Plate LXIV, figures 1a–d.

non *Scutella marginalis* Desmoulins, 1837, Études sur les échinides, Tabl. synon., p. 234.
non *Laganum marginale,* Agassiz and Desor, 1847, Cat. raisonné échinodermes, vol. 7, p. 133.
non *Sismondia marginalis* Desor, 1858, Synopsis des échinides, p. 226, Pl. XXVII, figs. 26–28.
Sismondia marginalis Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 75, no fig.
Mortonia (Periarchus) marginalis Conrad, 1866, Smithsonian Misc. Coll vol. 7 (200), p. 21.

Sismondia conradi Cotteau, 1891, Paléontologie française, Échinides éocènes, vol. 2, p. 300.
non *Sismondia marginalis* Cotteau, 1891, Paléontologie française, Échinides éocènes, vol. 2, p. 267.
Monostychia marginalis Gregory, 1891, Geol. Soc. America Bull., vol. 3, p. 105.
Periarchus (?) *marginalis* Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Determinative characters.—Test small in size; marginal outline subquadrate to suboval, the sides and posterior margin being truncated so that the posterior border is semiquadrate and the anterior border is semicircular; the whole form much depressed, though centrally it rises in the form of a low gently rounded mound; margin thin, with a small notch in the middle of the posterior edge; under surface flat. Ambulacral petals elliptical, extending about halfway to the margin. Apex and apical system central, or slightly excentric anteriorly. Peristome small, subcircular; ambulacral furrows simple and straight for over halfway to the margin, then becoming obscure. Periproct very small, subpentagonal or subcircular, inframarginal.

Dimensions.—Length 21 millimeters; width 21 millimeters; height 3 millimeters. This is Conrad's type, here figured for the first time.

Description.—The species, though described by Conrad in 1865, has never been figured and is not very well known. There is some doubt in regard to its generic position. Gregory's remark that it should be transferred to the genus Monostychia is not agreed to, for the reason that the type reveals five genital pores and fails to show any continuation of the actinal grooves abactinally. The test is small in size, the type being about $\frac{1}{2}\frac{3}{8}$ inch in diameter and about $\frac{1}{8}$ inch in height. In marginal outline it is subquadrate to suboval, with the sides and posterior margin truncated so that the posterior half of the border is semiquadrate and the anterior half semicircular. The upper surface is so much depressed all around the marginal area as to be quite flat, or even slightly concave, but within the area covered by the ambulacral petals it rises in the form of a low, gently rounded mound with a rather broad, flattened summit. The margin is thin, though slightly thicker than the submarginal area, with a small notch in the middle of the posterior side. The under surface is flat. The apex is central or slightly excentric anteriorly, at the summit of the tumid central area.

The ambulacral areas are narrow in the petaloid region, wider in the marginal region; but the condition of the specimen does not permit the making out of many details. The dorsal portions of the ambulacra are petaloid. The petals are subequal in length, elliptical in form, slightly open at the ends and extend about halfway to the margin. The poriferous zones are rather wide, but slightly less so than the interporiferous areas; the inner row of pores oval, the outer slitlike; the pairs of pores conjugated. A few pairs of pores occur beyond the ends of the petals.

The interambulacral areas are relatively large. The whole surface of the test is covered with small uniform tubercles, which are slightly larger on the under side.

The apical system is subcentral, at the summit of the central mound. The madreporite is relatively large, occupying the larger part of the area covered by the system, and faintly tumid. There are five genital pores near the edge of the madreporite and five small radial plates each perforated by a minute pore.

The peristome is small, subcircular, central; the ambulacral furrows simple, straight, and quite distinct for slightly more than half the distance to the margin, then becoming obscure. A small ridge extends from the peristome along the middle of each ambulacral furrow for a greater distance than the diameter of the peristome.

The periproct is very small, considerably smaller than the peristome, subpentagonal or subcircular, situated on the under surface near the posterior margin, being about one-fifth the radius from the border.

Related forms.—Of American forms *S. (?) conradi* most closely resembles *S. tuomeyi* and some of the smaller specimens of *Periarchus lyelli*, but is easily separated from these species by its subquadrate marginal outline and the inframarginal position of its periproct. It also resembles *S. mississippiensis*, but its periproct is less nearly marginal. It does not appear closely related to any of the known foreign forms.

Locality.—Conrad said his type came from near Charleston, S. C.

Geologic horizon.—Probably Cooper marl, upper Eocene.

Collection.—Academy of Natural Sciences of Philadelphia (1081).

Genus MORTONELLA Pomel.

non Mortonia Gray, 1851.
Mortonia Desor, 1857, Synopsis des échinides fossiles, p. 231.
Mortonella Pomel, 1883, Classif. méthodique et généra des échinides vivants et fossiles, p. 70.
Mortonella Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 684.

The genus Mortonella as used here includes the scutella-like forms having a central or subcentral apical system, periproct less than halfway from peristome to margin, thick margin, five genital pores, and ambulacral area either flat or tumid. The general form is discoidal. The ambulacral furrows are simple and straight for halfway to the margin, then bifurcate and proceed to the margin without much further branching. The ambulacral petals extend slightly more than halfway to the margin and are open at the ends. The chief difference between Mortonella and Periarchus is in the thickness of the margin.

MORTONELLA QUINQUEFARIA (Say).

Plate LX, figures 2a–2f; Plate LXI, figures 1a-b.

Scutella quinquefaria Say, 1825, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 5, p. 228, no fig.
non *Scutella rogersi* Morton, 1834, Synopsis organic remains Cretaceous, p. 77, Pl. XIII, fig. 3.
non *Scutella rogersi* Desmoulins, 1837, Études sur les échinides, Tabl. synon., p. 236.
non *Lagana rogersi* Agassiz, 1840, Cat. syst. ectyporum echinodermatum fossilium musei Neocomensis, p. 6. Merely listed Morton's form.
Scutella rogersi Agassiz, 1841, Mon. échinodermes vivans et fossiles, vol. 2, Des scutelles, pp. 85, 86, Pl. XIX, figs. 1–4. Described and figured Say's form under the impression that he was dealing with Morton's.
Scutella rogersi Agassiz (pars), 1847, Cat. raisonné échinodermes, vol. 7, p. 135.
Scutella rogersi Bronn (pars), 1848, Index palæontologicus, vol. 1, p. 1126; vol. 2, p. 196.
Mortonia rogersi Desor (pars), 1858, Synopsis des échinides fossiles, p. 231, no fig. Described Say's form but cited Morton's figure.
Mortonia rogersi Dujardin and Hupé, 1862, Hist. nat. des zoophytes échinodermes, p. 563.
Mortonia rogersi Conrad (pars), 1865, Acad. Nat. Sci. Philadelphia Proc., p. 74.
Mortonia quinquefaria (Say) Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 32.
Scutella rogersi Quenstedt, 1872–1875, Petrefact. Deutschlands, pt. 1, vol. 1, Echiniden, pp. 525, 546.
Mortonia rogersi Zittel, 1876–1880, Handbuch der palaeontologie, vol. 1, pt. 1, p. 522.
Mortonia rogersi Agassiz, 1883, Mus. Comp. Zoology Mem., vol. 10, No. 1, p. 88.
Mortonella rogersi Pomel, 1883, Classif. méth. et généra des échinides vivants et fossiles, Alger., p. 70.
Scutella mortoni (Agassiz) Quenstedt, 1885, Handbuch der Petrefactenkunde, p. 696.
Scutella (*Mortonia*) *rogersi* De Gregorio (pars), 1890, Mon. faune éocénique Alabama, p. 250, Pl. XLIII, figs. 16–20.
Mortonia quinquefaria Gregory, 1891 (discussion), Geol. Soc. America Bull., vol. 3, p. 105.
Echinanthus quinquefaria Gregory, 1891 (tabulation), Geol. Soc. America Bull., vol. 3, p. 105. This was evidently a lapsus calami.
Scutella rogersi Boyle, 1893, U. S. Geol. Survey Bull. 102, p. 263.
non *Mortonia rogersi* Dana, 1895, Manual of geology, 4th ed., p. 898, fig. 1491.
Mortonella rogersi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 685.

Determinative characters.—Test of medium size; discoidal; circular to broadly subovate in marginal outline; much depressed, upper surface more or less tumid centrally, margin and submarginal area thick; under surface flat. Ambulacral petals large, broad, spatulate, extending nearly two-thirds of the distance to the margin. Apex and apical system subcentral. Peristome small, circular; ambulacral furrows simple and straight nearly halfway to the margin, then forking symmetrically. Periproct very small, circular, about half the distance from peristome to posterior margin.

Dimensions.—Specimen A: Length 56 millimeters; width 58 millimeters; height 14 millimeters. Specimen B: Length 59 millimeters; width 61 millimeters; height 8 millimeters.

Description.—This species was one of the earliest Cenozoic forms reported from American deposits. It was first described by Thomas Say in 1825. Two specimens, which are probably Say's types, were found by the writer in the collection of the Academy of Natural Sciences of Philadelphia. This species has been often confused with *Clypeaster rogersi* (Morton), owing partly to a superficial resemblance, but more to the mistakes of L. Agassiz and Desor. Agassiz was the first to figure Say's form; but unfortunately having figured and described what was in reality

Say's *Scutella quinquefaria* he applied to the form Morton's name *Scutella rogersi*. The forms themselves are perfectly distinct, even belonging to different families, Say's form being one of the Scutillidæ and Morton's one of the Clypeastridæ; but, owing to the mistakes mentioned great confusion exists in regard to them in the various collections and in the literature. The separation of the two forms is not at all difficult, *Clypeaster rogersi* (Morton) being easily distinguished by its straight unbranched ambulacral furrows, its more concave under surface, its more tumid ambulacral petals, its less circular and more pentagonal marginal outline, and the location of its periproct nearer the posterior border.

This species is also interesting because on it Desor founded his genus Mortonia, based chiefly upon the unusually thick margin for a Scutella-like form. The name Mortonia was changed by Pomel to Mortonella because Gray had applied the name Mortonia to a different genus prior to Desor's use of it for the present genus.

The test of the present species is notably discoidal in form. It is of medium size, the dimensions varying but slightly from those already given. In most specimens it is usually circular in marginal outline, though in some it is broader posteriorly than anteriorly. The whole form is much depressed, the upper surface being either nearly flat or having a low, gently rounded central mound involving only about half of the region covered by the ambulacral petals. The variations in marginal outline and tumidity of the upper surface seem almost of specific value, but intermediate forms show a gradation from one to the other, and the variation in the character of the upper surface occurs in both the forms which are circular in marginal outline and those which are broader posteriorly. The region involving the outer part of each petal is faintly concave. The margin and submarginal area are thick, usually almost as thick as the average thickness of the test; the margin being slightly thinner and less rounded posteriorly than anteriorly, faintly undulating. The under surface is flat or broadly and faintly concave. The apex is subcentral, or slightly excentric anteriorly, at the summit of the more or less tumid central area.

The ambulacra are relatively wide in the petaloidal region, broader in the marginal region where they about equal the interambulacral areas. The dorsal portions are petaloid; the petals large, broad, subequal in length, the odd petal being slightly longer than the rest, spatulate in form, open at the ends and extending nearly two-thirds the distance from the center to margin. The poriferous zones are very wide, wider than the interporiferous areas; the inner row of pores nearly straight and composed of oval openings, the outer row slitlike; the pairs of pores conjugated.

The interambulacra are relatively narrow in the petaloidal region, wide in the marginal region, where about equal to the ambulacral areas, composed of large polygonal plates. The whole surface of the test, including the margins, is covered with small uniform tubercles which are slightly larger on the under side.

The apical system is subcentral or slightly excentric anteriorly at the summit of the test. The madreporite is relatively large, occupying the larger part of the area covered by the system and flush with the surface. There are five large genital pores near the edge of the madreporite and five small radial plates each perforated by a small pore.

The peristome is small, circular, central, the ambulacral furrows simple and straight nearly half the distance to the margin, then forking symmetrically, each pair of branches continuing almost to the margin. Each branch gives off on the outside one side branch at right angles about a fourth of the radius from the margin, which side branches soon bend and in turn approach the margin. A small ridge extends along the middle of each ambulacral furrow from the peristome to the fork in the furrow.

The periproct is very small, circular, situated on the under surface about half the way from the peristome to the posterior margin.

Related forms.—The thick margin and discoidal form of *Mortonella quinquefaria* afford a ready means of separating it from most American echinoids. *Dendraster perrini* is similar in having a thick margin but differs in having its apical system posteriorly excentric, its ambulacral

petals relatively longer and wider open at the ends, and its periproct inframarginal. *Periarchus lyelli* also resembles *M. quinquefaria* in general but has a thin margin. Of foreign forms *Scutella faujasi* De France from the middle Tertiary of France is closely related to this species. The specimen *S. faujasi* figured by Bronn in Lethæa geognostica, Plate XXXVI, figure 8, shows the thick margin, discoidal outline, and similarly branching ambulacral furrows.

Localities.—Near Milledgeville (Say's types); 1 mile southwest of Sandersville (figured specimen A); Washington County (figured specimen B); 1½ miles northeast of Tenville; Norton; and 2½ miles south of Warthen, Washington County, Ga.

Geologic horizon.—Claiborne group, middle Eocene, and Jackson formation,(?) upper Eocene.

Collections.—U. S. National Museum (9500, A); Academy of Natural Sciences of Philadelphia: Wagner Free Institute of Science; Geological Survey of Georgia; Amherst College (B).

Genus PERIARCHUS Conrad.

Periarchus Conrad, 1866 (subgenus), Smithsonian Misc. Coll., vol. 7 (200), p. 21.
Periarchus Grabau and Shimer, 1910, North Am. index fossils, vol. 2, p. 591.
Periarchus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 687.

The genus Periarchus as used here includes the Scutella-like forms with central or subcentral apical system, periproct actinal, but less than three-fifths of the way from the peristome to the margin, thin margin, five genital pores and more or less abruptly tumid ambulacral area. The ambulacral furrows are usually simple and straight about halfway to the margin, then bifurcate and proceed to the margin without much further branching. The ambulacral petals are usually short, rarely extending more than halfway to the margin, more or less open at the ends.

Periarchus altus Conrad.

Plate LVIII, figures 1a–e.

Scutella sp. Emmons, 1858, Agriculture Eastern Counties: North Carolina Geol. Survey Rept., p. 308, figs. 247, 248.
Sismondia alta Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., pp. 74, 75, no figure.
Mortonia (*Periarchus*) *altus* Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 21.
Mortonia (*Periarchus*) *altus* Heilprin, 1884, Contr. Tertiary geology U. S., p. 17.
Sismondia alta Cotteau, 1889–1894, Paléontologie française, Échinides éocènes, vol. 2, p. 300.
Periarchus altus Gregory, 1891, Geol. Soc. America Bull., vol. 3, p. 105.
Periarchus altus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 699.
Periarchus sp. *b* Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 699.

Determinative characters.—Test of medium size, circular in marginal outline, much depressed, less so centrally where it rises in a relatively high, broad, obliquely flattened mound, whose apex is noticeably excentric anteriorly; margin of sides and posterior end thin, anteriorly the upper surface declines in a straight line from apex to edge; under surface flat. Ambulacral petals subelliptical, relatively large, extending about halfway to the margin. Apical system slightly excentric posteriorly, and well to the rear of the apex. Peristome small, circular, slightly excentric posteriorly; ambulacral furrows simple and straight for slightly more than half the way to the margin, then forking symmetrically. Periproct very small, subcircular, about two-fifths the way from the peristome to the posterior border.

Dimensions.—Length 57.5 millimeters; width 59 millimeters; height 12 millimeters. This is the type, refigured.

Description.—This species was figured and partly described by Emmons as early as 1858. He placed it in the genus Scutella but did not give the form a specific name. In 1865 Conrad, who had seen Emmons's type, gave a good description of it and applied the appropriate specific name *alta* but he did not figure it. It is rare, only the one specimen found by Emmons having yet been reported. The test is of medium size. The marginal outline is circular. The upper surface rises centrally in the form of a low broad mound, whose apex is noticeably forward of the center; anteriorly the surface declines in a straight line from the apex to the edge; along the posterior margin it is greatly depressed and nearly flat from the edge to the petaloid region, then rises at first rather steeply then more gently to the apex. The relative height of the central

mound is greater than in most forms likely to be confused with it, being more than one-fifth of the diameter of the test. The margin of the sides and posterior end is thin. The under surface is flat, or faintly concave between the margin and the region around the peristome. The apex is noticeably excentric anteriorly at the summit of the tumid area.

The ambulacral areas are relatively wide in the petaloid region though wider in the marginal region, in both cases being wider than the interambulacral areas. The dorsal portions of the ambulacra are petaloid. The petals are relatively large and broad; subequal in length the posterior pair being slightly shorter than the rest, subelliptical in form; slightly pointed at the ends; extending slightly more than halfway to the margin. The poriferous zones are rather wide, but less so than the wide interporiferous areas; the inner row of pores oval, outer row slit-like; pairs of pores conjugated. A few pairs of pores occur beyond the ends of the petals.

The interambulacral areas are relatively small between the petals and though wide near the margin in both cases are smaller than the ambulacral areas; composed of large polygonal plates. The whole surface of the test is covered with small uniform tubercles, which are slightly larger on the under side.

The apical system is slightly excentric posteriorly, located well back of the apex on a flattened area which extends obliquely downward and backward from the apex and is about three times the diameter of the system. The madreporite is relatively large, occupying the larger part of the area covered by the system, subpentagonal, flush with the surface. There are five large circular genital pores perforating the basal plates at the points of the madreporic pentagon, and five small radial plates, each perforated by a minute pore.

The peristome is small, circular, slightly excentric posteriorly; the ambulacral furrows simple and straight for slightly more than half the distance to the margin, then forking symmetrically, and at rather a wide angle, each pair of branches continuing nearly to the margin. A small ridge extends out for a short distance from the peristome along the middle of each ambulacral furrow.

The periproct is very small, subcircular, situated on the under surface about two-fifths of the way from the peristome to the posterior border. It is nearer the peristome than are the forks in the ambulacral furrows.

Related forms.—The species is most closely related to *P. lyelli*, from which, however, it is easily distinguished by its anteriorly excentric apex, by the noncoincidence of its apical system and apex, by the fact that the central tumid mound involves nearly the whole upper surface instead of being confined to the petaloid region, and by its broader petals. No foreign forms appear to be closely related to this species.

Locality.—Core Creek, Craven County, N. C.

Geologic horizon.—Trent marl, middle Eocene.

Collection.—Williams College.

Periarchus lyelli Conrad.

Plate LXI, figures 2a–f; Plate LXII, figures 1a–c, 2a–d.

Scutella lyelli Conrad, 1834, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 7, p. 152, no figure.

?*Scutella lyelli* Morton, 1834, Synopsis organic remains Cretaceous, p. 77, Pl. X, fig. 8. Figure shows upper surface only; no description.

Scutella lyelli Conrad, 1842, Nat. Inst. Promotion Sci. Proc., 2d Bull., p. 175.

?*Scutella lyelli* Bronn, 1848, Index paleontologicus, vol. 1, p. 1126; vol. 2, p. 196. Based on Morton.

?*Sismondia lyelli* Desor, 1858, Synopsis des échinides, p. 227. Based on Morton.

non *Scutella lyelli* Emmons, 1858, Agriculture Eastern Counties, North Carolina Geol. Survey Rept., p. 308, text fig. 246.

?*Scutella lyelli* Gabb, 1859, Cat. invert. fossils Cretaceous, p. 19. Based on Morton.

?*Scutella lyelli* Dujardin and Hupé, 1862, Hist. nat. zoophytes échinodermes, p. 559. Based on Morton.

Sismondia lyelli Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 74.

Mortonia (*Periarchus*) *lyelli* Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 21.

?*Scutella lyelli* Agassiz, 1883, Mus. Comp. Zoology Mem., vol. 10, No. 1, p. 89. Based on Morton.

non *Scutella lyelli* Heilprin, 1884, Contrib. tertiary geology U. S. p. 17.

Scutella lyelli Smith and Johnson, 1887, U. S. Geol. Survey Bull. 43, p. 21.

?*Sismondia lyelli* Cotteau, 1889–1894, Paléontologie française, Echinides éocènes, vol. 2, p. 301. Based on Morton.

Scutella lyelli De Gregorio, 1890 (pars), Mon. faune éocénique Alabama, pp. 250–251, Pl. XLIII, fig. 21. Conrad's description but Morton's figure.
Scutella lyelli Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
?*Scutella lyelli* Boyle, 1893, U. S. Geol. Survey Bull. 102, p. 263. Based on Morton.
Periarchus sp. *a*. Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 696.
?*Sismondia* (?) *lyelli* Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Determinative characters.—Test variable in size, subcircular to subovate in marginal outline; much depressed, less so centrally where it rises in a gently rounded, convex mound of variable height; margin and wide submarginal area thin; under surface flat. Ambulacral petals subelliptical to suboblong, extending about half way to the margin. Apex and apical system central or subcentral, on the somewhat flattened summit of the tumid area. Peristome small, subcircular; ambulacral furrows simple and straight for about half way to the margin, then forking symmetrically. Periproct very small, subcircular, from one-third to slightly more than halfway from peristome to posterior border.

Dimensions.—Specimen A: Length 90 millimeters; width 90 millimeters; height 12 millimeters. Specimen B: Length 32 millimeters; width 31 millimeters; height 6 millimeters. Specimen C: Length 35 millimeters ; width 34 millimeters; height 5 millimeters.

Description.—Considerable confusion exists in regard to this and allied forms in the various collections and in the literature. Conrad as early as 1834 gave an excellent description of the species but no figure. The same year Morton published a poor upper view only of a small form which he called *Scutella lyelli* Conrad, but gave no description. Conrad's form was a large specimen from Alabama, forms similar to which have easily been identified among the material studied by the writer. Morton's specimen was a small one, whose present whereabouts is unknown, and was from a locality which is uncertain. Desor, Cotteau, and others, basing their action upon Morton's figure, have placed the species *lyelli* in the genus Sismondia. This is an error, as Conrad's form has all the characters of Periarchus. Unless his figured specimen is discovered, Morton's form must remain of doubtful character and is therefore placed among the doubtful and unrecognized species.

Periarchus lyelli is one of the most abundant of the American Cenozoic forms, at times occurring in such numbers and with such constancy as to afford a valuable aid in determining the geologic horizon in which it is found. The test is variable in size, ranging from 1 to 3½ inches in diameter. In marginal outline it is circular or subcircular to subovate, some specimens slightly others decidedly broader posteriorly than anteriorly. All around the area outside the ambulacral petals it is greatly depressed and quite flat; but within the petaloidal area it rises in the form of a gently rounded mound with more or less flattened summit, which ranges from ¼ to ½ inch in height according to the size and age of the specimen. Sometimes the mound approaches a subconical form, but even then the sides are more or less convex. The margin of the test is thin and slightly undulating, both characters being most pronounced posteriorly; usually there are broad shallow notches opposite the ends of the posterior petals, though these may be inconspicuous or absent in the smaller specimens. The flattened marginal area, from the ends of the petals to the edge, is thin and wide, being about as wide as, or wider than the petals are long, and usually widest posteriorly. The under surface is flat or nearly so with a broad faintly depressed ring about midway between margin and peristome. The apex is central or slightly excentric anteriorly, at the summit of the tumid area.

The ambulacral areas are narrow in the petaloid region but wide at the margin where they about equal the interambulacral areas. The dorsal portions are petaloid. The petals are of medium size; subequal in length, the odd petal being slightly longer than the rest; subelliptical to elongate elliptical or suboblong in form; slightly open at the ends; extending half or slightly more or less than half the way to the margin. The poriferous zones are rather wide, almost as wide as the interporiferous areas; inner rows of pores nearly straight and parallel and formed of oval pores, outer rows of pores slitlike; pairs of pores conjugated. A few pairs of pores occur beyond the ends of the petals.

The interambulacral areas are large, relatively wide between the petals (usually wider than the ambulacral areas), nearly uniform, and composed of large polygonal plates. The

whole surface of the test is covered with small uniform tubercles which are slightly larger on the under side.

The apical system is central or slightly excentric anteriorly, on the somewhat flattened summit of the central mound. The madreporite is relatively large, occupying the larger part of the area covered by the system and flush with the surface. There are five genital pores near the edge of the madreporite and five small radial plates each perforated by a small elliptical pore.

The peristome is small, subcircular, central or slightly excentric anteriorly; the ambulacral furrows simple and straight for from one to two-thirds the distance to the margin, then forking symmetrically at an angle usually of about 45°, each pair of branches continuing almost to the margin. On well-preserved specimens, each branch may be seen to give off on the outside one important side branch at right angles about halfway between the fork and the margin, which side branches soon bend and in turn approach the margin. A small ridge extends out from the peristome for a short distance along each ambulacral furrow.

The periproct is very small, about half the diameter of the peristome, circular or subcircular, situated on the under surface from one-third to slightly more than one-half the way from the peristome to the posterior border.

Related forms.—This species presents so many variable features that several apparently distinct varieties of it might have been recognized and separately described—such as one with a transversely elongate subtriangular marginal outline, or one with periproct midway between margin and peristome—but in each case intermediate forms show a gradation between the possible variety and typical representatives of the species. *P. lyelli* Conrad is closely related to the American forms *P. pileus-sinensis* and *P. protuberans*, both of which, however, have a relatively higher and more conical central tumid area. *P. protuberans* is further distinguished by its characteristic swollen anterior interporiferous area and smaller petaloid area. *P. lyelli* also greatly resembles *S. tuomeyi* which, however, differs in being somewhat truncated posteriorly and in having its periproct nearer the posterior border. In superficial characters *P. lyelli* greatly resembles *S. mississippiensis*, but the latter is easily separated by the inframarginal position of its periproct. It does not appear to be closely related to any of the foreign forms.

Localities.—Near Claiborne (Conrad's type and our specimen A); Cedar Creek, Clarke County; St. Stephens, near Cocoa, Choctaw County; and Clarksville, Ala.; Shubuta Creek, 2½ miles north of Shubuta; Chickasawhay River, near Shubuta; and Shell Prairie, near Pachuta, Miss.; 14 miles below Macon, Twiggs County, Ga.; Mount Enterprise, Rusk County, and 2 miles east of Alto, Cherokee County, Tex.; Castle Hayne (specimen B); City Rock Quarry, Smith Creek; and Rocky Point, near Wilmington, N. C.

Geologic horizon.—Claiborne group (middle Eocene) and Jackson formation (upper Eocene). In Texas in the "marine substage" of the Claiborne. In Mississippi probably near the base of the Lisbon marl. In Alabama abundant in the *Scutella* zone at the base of the Jackson, "just above the Claiborne fossiliferous sand." In North Carolina, in the Castle Hayne limestone (upper Eocene or Oligocene).

Collections.—Boston Society of Natural History (larger figured form) (1553, A); U. S. National Museum (smaller figured form); Alabama Geological Survey; American Museum of Natural History; Wagner Free Institute of Science; Williams College; Amherst College; Johns Hopkins University (T 2003, B; T 2004, C).

Periarchus protuberans Twitchell, n. sp.

Plate LXII, figures 3a–f.

Determinative characters.—Test of medium size, subcircular in marginal outline; much depressed, less so centrally where it rises in a high, slightly asymmetric cone; margin very thin, broadly dentate posteriorly; under surface flat. Ambulacral petals elliptical, very small, extending about one-third the distance from center to margin. The anterior interporiferous area swollen near the apical system which is slightly excentric posteriorly and inclined downward and backward from the subcentral apex. Peristome very small, circular, in a slight concavity; ambulacral furrows simple and straight for about half way to the margin, then forking

symmetrically. Periproct very small, oval or subovate, on the under surface about one-fourth the distance from the peristome to the posterior margin.

Dimensions.—Length 54 millimeters; width 53 millimeters; height 9 millimeters.

Description.—This new species is one of the handsomest of American scutellid forms. It is very delicate and fragile and so thin that it is translucent from the edge halfway to the center. It is a rare form, not over half a dozen individuals having been reported, all of which are from the Eocene deposits of Mississippi, where it occurs in association with *P. pileus-sinensis* and *P. lyelli*. The test is of medium size, ranging from 1½ to 2½ inches in diameter; and subcircular in marginal outline. All around the area from the edge nearly to the petals it is greatly depressed and nearly flat; but within and slightly beyond the petaloidal area it rises in the form of a high, slightly unsymmetrical cone which varies in height from ⅜ to ½ an inch. The margin of the test is very thin all around, almost like a knife edge, and is decidedly undulating, or zigzag, especially posteriorly, where it is broadly dentate. The under surface, though for the most part flat, is slightly and broadly concave around the margin and the peristome. The apex is subcentral at the summit of the central cone.

The ambulacral areas are narrow in the petaloid region but wide in the marginal region where they about equal the interambulacral areas. The dorsal portions are petaloid. The petals are subequal in length, the odd petal slightly longer than the rest; relatively quite small, extending only about two-fifths the distance from center to margin, the total area covered by the petals being noticeably less than in most similar forms. The petals are elliptical in form and nearly closed at the ends; the poriferous zones rather wide though less so than the interporiferous areas, widest at their distal ends; the inner row of pores oval, outer row slitlike; the pairs of pores conjugated. The anterior interporiferous area is swollen near the apical region so as to form a small, narrow protuberance, confined within the interporiferous area, largest nearest the apical system and constituting the apex of the test. This protuberance is one of the most striking and most distinctive features of the form; and suggested the specific name.

The interambulacral areas are large, nearly uniform, and composed of large polygonal plates. The whole surface of the test is covered with small uniform tubercles which are slightly larger on the under side.

The apical system is slightly excentric posteriorly, inclined downward and backward from the swollen anterior interporiferous area, on the steep posterior slope of the central subconical mound. The madreporite is relatively large, occupying the larger part of the area covered by the system. There are five genital pores near the edge of the madreporite, and five small radial plates, each perforated by a small elliptical pore.

The peristome is very small, not much larger than the periproct, circular, central, in a slight concavity; ambulacral furrows simple and straight for about one-half the distance from peristome to margin, then forking symmetrically, each pair of branches continuing nearly to the margin and each branch giving off one important side branch at right angles at one-third to one-fourth radius length from the margin; these side branches soon bend and in turn approach the margin. A small ridge extends for a short distance along the middle of each ambulacral furrow.

The periproct is very small, oval or subovate in outline, the round end being nearest the peristome, on the under surface from one-fourth to one-third the distance from peristome to the posterior margin. It is much nearer the peristome than are the forks in the ambulacral furrows.

Related forms.—*P. protuberans* is very similar in appearance to *P. pileus-sinensis* (Ravenel), resembling it more closely than it does any other American form. It is, however, readily distinguished by its protuberant anterior interporiferous area, smaller petaloidal area, the position of its apical system to the rear of the apex, its thinner marginal area, smaller peristome, and the nearer approach of its periproct to the peristome. No foreign forms appear to be closely related to this species.

Localities.—Shubuta Creek, 2½ miles north of Shubuta (type), and Chickasawhay River, Shubuta, Miss.

Geologic horizon.—Jackson formation, upper Eocene.

Collection.—U. S. National Museum (164685).

Periarchus pileus-sinensis (Ravenel).

Plate LXIII, figures 1a–e, 2a–d

Scutella pileus-sinensis Ravenel, 1844, Acad. Nat. Sci. Philadelphia Proc., vol. 2, p. 97–98, no figure.
Scutella pileus-sinensis Ravenel, 1850, Am. Assoc. Adv. Sci. Proc., vol. 3, p. 160.
Sismondia pileus-sinensis Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 74.
Mortonia (Periarchus) pileus-sinensis Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 21.
Periarchus pileus-sinensis Gregory, 1891, Geol. Soc. America Bull., vol. 3, p. 105.
?*Scutella caput-linensis* Kennedy, 1891, Texas Geol. Survey Third Ann. Rept., pp. 55, 56.
?*Scutella caput-sinensis* Kennedy, 1895, Acad. Nat. Sci. Philadelphia Proc., pp. 113, 114, 115.
Periarchus pileus-sinensis Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 688.

Determinative characters.—Test of medium size, subcircular in marginal outline, much depressed, less so centrally where it rises in a high well-defined cone with straight or concave sides; margin and submarginal area thin; under surface flat. Ambulacral petals elongate-elliptical, extending more than halfway to the margin. Apical system, central or slightly excentric anteriorly, forming the summit of the central conical area. Peristome small, circular, ambulacral furrows simple and straight for more than one-third of the distance to the margin then forking symmetrically. Periproct very small, subcircular, slightly more than one-third the way from peristome to posterior border.

Dimensions.—Specimen A: Length 79 millimeters; width 76 millimeters; height 16 millimeters. Specimen B: Length 65½ millimeters; width 67 millimeters; height 14 millimeters.

Description.—This species was first described by Ravenel from the Eocene deposits of South Carolina in 1844. His name, *pileus-sinensis* or "Mandarins hat," is most appropriate for the form, as may readily be seen by a glance at the side view. The form is rather abundant in certain localities, sometimes occurring in association with *Periarchus lyelli* and *Periarchus protuberans*. The test is of medium size, ranging from 2¼ to 3¼ inches in diameter. In marginal outline it is almost circular, though slightly broader posteriorly than anteriorly. All around the area outside the ambulacral petals it is greatly depressed and nearly flat; but within the petaloidal area it rises in a high well-defined cone with straight or concave sides. The height of the cone is somewhat variable but in the larger forms it usually rises to over half an inch. The margin of the test is thin and slightly undulating, both characters being most pronounced posteriorly. In some specimens the submarginal area is thinner than the edge. There is usually a more pronounced notch in the margin opposite the ends of the posterior paired ambulacral petals. The under surface is flat, even faintly concave between the margin and the region around the peristome. The apex is slightly excentric anteriorly, at the summit of the central conical area.

The ambulacral areas are narrow in the petaloid region, wider in the marginal region where they equal or slightly exceed the width of the interambulacral areas. The dorsal portions are petaloid. The petals are subequal in length, the anterior paired petals being slightly shorter than the other three; elongate elliptical in form; extending more than halfway to the margin, the odd petal usually approaching the margin more nearly than the rest; slightly open at the ends. The poriferous zones are rather wide, about equal to the interporiferous areas; the inner row of pores oval, the outer slitlike; the pairs of pores conjugated. A few pairs of pores occur beyond the ends of the petals.

The interambulacral areas are large, nearly uniform, and composed of large polygonal plates. The whole surface of the test is covered with small uniform tubercles, which are slightly larger on the under surface.

The apical system is subcentral or slightly excentric anteriorly at the summit of the conical area. The madreporite is relatively large, occupying the larger part of the area covered by the system and is somewhat tumid. There are five genital pores near the edge of the madreporite and five small radial plates each perforated by a small elliptical pore.

The peristome is small, circular, central or slightly excentric anteriorly; ambulacral furrows simple and straight for more than one-third the distance from peristome to margin, then forking symmetrically, each pair of branches continuing nearly to the margin, each branch giving off one important side branch at right angles at a point from one-third to one-fourth the radius of

the test from the margin, which side branches soon bend and in turn approach the margin. A small ridge extends along the center of each ambulacral furrow for a short distance away from the peristome.

The periproct is very small, subcircular, on the under surface at a little more than one-third the distance from the peristome to the posterior margin. It is sometimes nearer, sometimes farther from the peristome than are the forks in the ambulacral furrows.

Related forms.—*P. pileus-sinensis* is very closely related to *P. lyelli* and *P. protuberans*. From the former it is best distinguished by its higher and straight or concave-sided central cone; and from the latter by its lacking the swollen anterior interporiferous area at the apex. No foreign forms appear to be closely related to this species.

Localities.—The type was from "about 6 miles south of Black Oak Lock of the Santee Canal, St. Johns Parish, S. C." The figured specimen came from "the Santee Canal, S. C." Other localities are Santee River, S. C.; near Tivoli, Beachhaven Park, Limestone Creek, Towers, Rich Hill, Crawford County; Shellstone Creek, 2 miles south of Perry, Houston County; and Ring Jaw Landing, Oconee River, Ga.; 1 mile west of Cocoa, Choctaw County; and Claiborne and below mouth of Cedar Creek, Clarke County, Ala.; Chickasawhay River at Shubuta, Shubuta Creek, 2½ miles north of Shubuta, and Shell Prairie near Pachuta, Miss.

Geologic horizon.—Jackson formation, upper Eocene. In South Carolina in the Cooper marl, of Jackson age. In Georgia in the Vicksburg or Jackson formation.

Collections.—U. S. National Museum (5133, A; 137791, B); Amherst College; Boston Society of Natural History; American Museum of Natural History; University of South Carolina.

Family CLYPEASTRIDÆ.

Genus CLYPEASTER Lamarck.

Clypeaster rogersi (Morton).

Plate LXIV, figures 2a–d, 3a–d.

Scutella rogersi Morton, 1834, Synopsis organic remains Cretaceous, p. 77, Pl. XIII, fig. 3.
Lagana rogersi Agassiz, 1840, Cat. syst. ectyporum Echinodermatum fossilium musei Neocomensis, p. 6. Merely listed Morton's form.
non *Scutella rogersi* Agassiz, 1841, Mon. échinodermes vivans et fossiles, vol. 2, Des scutelles, pp. 85, 86, Pl. XIX, figs. 1–4. Described and figured *Mortonella quinquefaria* (Say) under the impression that he was dealing with Morton's form.
Scutella rogersi Morton, 1842, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 8, p. 218.
Scutella jonesii Forbes, 1845, Geol. Soc. London Proc., vol. 4, p. 574, text figure.
Scutella jonesii Forbes, 1845, Geol. Soc. London Quart. Jour., vol. 1, p. 440, text figure.
Scutella rogersi, Agassiz (pars), 1847, Cat. raisonné échinodermes, vol. 7, p. 135.
Scutella rogersi Bronn (pars), 1848, Index palæontologicus, vol. 1, p. 196; vol. 2, p. 1126.
Scutella jonesii Bronn, 1848, Index palæontologicus, vol. 1, p. 196; vol. 2, p. 1126.
Clypeaster jonesii Desor, 1858, Synopsis des échinides fossiles, p. 243.
Mortonia rogersi Desor (pars) (figure cited only), 1858, Synopsis des echinides fossiles, p. 231.
Scutella rodgersi Gabb, 1859, Cat. invert. fossils Cretaceous, p. 19.
non *Clypeaster ambigenus* Michelin, 1861, Soc. géol. France Mém., 2d ser., vol. 7, p. 113.
Clypeaster jonesii Dujardin and Hupé, 1862, Hist. nat. zoophytes échinodermes, p. 573.
Mortonia rogersi Conrad (pars), 1865, Acad. Nat. Sci. Philadelphia Proc., p. 74.
Mortonia jonesii Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 74.
Mortonia turgida Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., vol. 17, p. 184, no figure.
Clypeaster jonesii Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 74.
? *Mortonia tumida* Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), pp. 22, 37 (note).
Clypeaster jonesii Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 22.
? *Clypeaster tumidus* Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), pp. 22, 37 (note).
Clypeaster rogersi Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 22.
Scutella (mortonia) rogersi De Gregorio (pars), 1890, Mon. faune éocénique Alabama, p. 250, Pl. XLIII, figs. 16–20.
Clypeaster rogersi De Loriol, 1890, Soc. phys. hist. nat. de Geneva Mém., vol. suppl. du centenaire, p. 99.
Scutella rogersi Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Echinanthus rogersi Gregory, 1891 (discussion), Geol. Soc. America Bull., vol. 3, p. 105.
Mortonia rogersi Gregory, 1891 (tabulation), Geol. Soc. America Bull., vol. 3, p. 105. This was evidently a lapsus calami.
Scutella rogersi Boyle, 1893, U. S. Geol. Survey Bull. 102, p. 263.

Mortonia rogersi Dana, 1895, Manual of geology, 4th ed., p. 898, fig. 1491.
Clypeaster douvillei Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 682, Pl. XXII, figs. 1a–c.; p. 698.
Clypeaster jonesi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 705.
Clypeaster turgidus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 698.

Determinative characters.—Test medium in size; subpentagonal to suboval, anterior end rounded, posterior end truncated at the corners and centrally, longer than broad, usually widest opposite ends of anterior petals; much depressed, upper surface rising more or less gradually from the rather thick margin to the low central apex, sometimes regularly arched or of convex outline from margin to margin, sometimes subconical centrally; under surface flat around the margin, concave centrally. Ambulacral petals large, tumid, elliptical, anterior pair shorter than the rest which are about equal, all extending from about one-half to two-thirds the way to the margin, wide open at the ends; poriferous zones wide, outer rows of pores depressed below the general surface. Apical system central; genital pores five. Peristome medium in size, central; ambulacral furrows simple, straight, well defined, reaching the margin. Periproct small, inframarginal; situated from one-fifth to one-sixth the distance from the margin to the peristome.

Dimensions.—Specimen A: Length 70 millimeters; width 63.5 millimeters; height 16.5 millimeters. Specimen B: Length 45 millimeters; width 43.5 millimeters; height 17 millimeters.

Description.—The species, to judge from the number of specimens reported, is the most abundant of American clypeasters, being rather common in the Jackson and Vicksburg formations of Mississippi, Alabama, and Georgia. It is also one of the first species of echinoids discovered in American Cenozoic deposits, having been figured and described by Morton in 1834. This species has been frequently confused with *Mortonella quinquefaria* (Say), partly because of a resemblance in general appearance, but more because of certain mistakes in identification made by L. Agassiz and by Desor. In 1841 Agassiz described and figured a specimen of *Mortonella quinquefaria* (Say) under the impression that he was dealing with one of *Clypeaster rogersi* (Morton). In 1858 Desor made matters worse by describing Say's form and founding upon it the new genus Mortonia; but, instead of figuring it, citing as a good illustration Morton's figure of *C. rogersi*. As a result of these mistakes many specimens were found mislabelled in the various collections studied and the synonymy of the two forms was found to be in a tangle requiring considerable labor to unravel. *M. quinquefaria* can easily be separated from the present species by its more circular outline and discoidal form, less tumid petals, less concave under surface, branching ambulacral furrows, and the more distant position of its periproct from the posterior border. About ten years after Morton's description of the present species was published, Lyell collected in Georgia some specimens which were described and figured by Forbes and given the new specific name of *Scutella jonesii*, but a careful study of the figures and descriptions, aided by an extensive series of specimens, although without the types, fails to reveal any essential differences between the two forms. Conrad's *Mortonia turgida*, which he appears to have also called *Mortonia tumida* and still later *Clypeaster tumidus* was probably a specimen of *C. rogersi*, which was tumid centrally.

The test of *Clypeaster rogersi* is of medium size, ranging from about 1½ to about 3 inches in length. In marginal outline it is somewhat variable, being subpentagonal in most specimens though nearly oval in others; the anterior end is usually rounded; the posterior end is truncated centrally, with corners either truncated or rounded; the sides are either straight, slightly convex, or slightly concave; the longitudinal diameter exceeds the transverse; most specimens are broadest opposite ends of anterior petals, but some are broadest centrally. The whole form is greatly depressed, the upper surface either rising gradually and gently from the margin to the apex and showing an almost regularly arched or convex outline from margin to margin when viewed from the side or end, or rising centrally in a subconical mound involving the petaloidal area; apex central, low, its height rarely exceeding one-fourth the width of the test; margin thick and rounded anteriorly, becoming thinner and more wedge-shaped posteriorly. The under surface flat, or nearly so, around a wide marginal area, concave centrally; the concavity increasing more rapidly as the peristome is approached, the depth of the concavity being about one-third the height of the test.

The ambulacral areas are rather wide, both at the margin and across the middle of the petals, in both cases wider than the interambulacral areas; dorsal portions petaloid. The petals are rather large, elliptical to subspatulate in form, anterior pair slightly shorter than the rest which are about equal in length, all extending from about one-half to two-thirds the way to the margin, moderately to widely open at the ends. The poriferous zones are wide, inner rows of pores elevated, nearly straight, either nearly parallel or slightly diverging and consist of round openings; outer row of pores depressed below the general surface, curving and composed of slitlike openings; pairs of pores conjugated; interporiferous areas varying in width from only slightly wider than poriferous zones to nearly twice as wide, elevated so that the petals are somewhat tumid.

The interambulacral areas are wide opposite the ends of the petals, rather narrow at the margin. The whole surface of the test, including even the ridges between the pairs of pores of the poriferous zones, is covered with very small, uniform imperforate tubercles, set in rather deep scorbicules. The tubercles are slightly larger on the under surface.

The apical system is central, coincident with the apex. There are five genital pores at the tips of the points of the almost star-shaped madreporite; and five small ocular plates extending between the points of the star, each perforated by a minute pore. The apical system, together with a very small area immediately surrounding it and involving the inner ends of the petals, is elevated slightly above the rest of the test.

The peristome is medium in size, central, subcircular to subpentagonal, and situated at the deepest portion of the concavity on the under surface. The ambulacral furrows are simple, straight, well defined, extending from peristome to margin; on well-preserved specimens they can be seen to continue as a faint line over the margin and along the middle of the ambulacral petals nearly to the apical system.

The periproct is small, subcircular, inframarginal, from one-fourth to one-sixth of the distance from the margin to the peristome.

Related forms.—Clypeaster rogersi is not closely related to any American species, but resembles a number of foreign forms in general appearance, and is very similar to several of them. *C. biarritzensis* Cotteau, from the upper Eocene of France, greatly resembles the present species, but its ambulacral petals are more nearly equal (or, if there is any difference, the odd petal is the longest), its interporiferous areas are relatively wider, and its poriferous zones relatively narrower, more divergent, and therefore more widely apart at the ends. *C. simplex* Duncan and Sladen, from the Oligocene of Western Sind, India, also closely resembles *C. rogersi*, but differs in having petals which are longer and tend to close more nearly at the ends. Two species from the Miocene of Cuba, *C. concavus* Cotteau and *C. cotteaui* Egozcue, resemble *C. rogersi* in certain points; but both are relatively higher than the present species and *C. cotteaui* has straighter and more widely divergent poriferous zones. Michelin [1] stated that he regarded *C. jonesii* Forbes (which is here regarded as a synonym of *C. rogersi*) as the young of *C. ambigenus* De Blainville, a recent West Indian species. The writer can not agree with this view, as *C. ambigenus* is considerably higher, less concave on the under surface, and has more elliptical interporiferous areas due to the more curving character of the inner rows of pores of the poriferous zones. Stefanini's *C. douvillei* appears to be a *C. rogersi* with relatively thin margin and subconical upper surface, such as the writer has found to grade into the more typical representatives of the species.

Localities.—Near Shubuta, 5 miles west of Shubuta, Vicksburg, and Jackson, Miss.; St. Stephens Bluff, 9 miles north of St. Stephens, 5 miles south of Claiborne, Gainestown, near Rescueville, Choctaw County, near Claiborne, and Clarksville, Ala.; Hawkinsville, and 5 miles southwest of Hawkinsville, Ga.

Geologic horizon.—Jackson formation, upper Eocene; Vicksburg formation, lower Oligocene.

Collections.—U. S. National Museum (137801, A and 155377, B); Geological Survey of Alabama; Boston Society of Natural History; Academy of Natural Sciences of Philadelphia; Wagner Free Institute of Science.

[1] Monographie des Clypéastres fossiles: Soc. géol. France Mém., 2d ser., vol. 7, p. 113, 1861.

Genus ECHINANTHUS Leske.

Echinanthus georgiensis Twitchell, n. sp.

Plate LXV, figure 1a–d.

Determinative characters.—Test subpentagonal, broadest posteriorly, anterior end straight, posterior end pointed, notched and rostrate, upper surface depressed, convex, with a longitudinal keel along the posteromedian area; under surface concave around the peristome; apex forward of the center. Ambulacral areas narrow; dorsal portions petaloid, petals narrow and rather short. Apical system small, anteriorly excentric. Peristome subpentagonal, transversely elongate, anteriorly excentric, with well-developed floscelle. Periproct small, oval, marginal, at the top of a vertical sulcus which notches the posterior end, and beneath a slightly overhanging projection of the keel.

Dimensions.—Length 42 millimeters; width 41 millimeters; height 18 millimeters.

Description.—The species, the first of the genus Echinanthus to be reported from the United States, is very rare, only a single specimen having been found up to the present time. It is of especial interest because it is one of the earliest of the Cenozoic echinoids, the type having been found in the Midway formation of Georgia. The test is subpentagonal in marginal outline, broadest back of the center, from which it narrows both anteriorly to the straight anterior edge and posteriorly to the pointed posterior end; margin angular all around, rostrate posteriorly, with a notch at the posterior end which can be seen from both above and below. The upper surface is depressed, convex, declining rather steeply on all sides from the apex, with a rounded longitudinal keel along the posteromedian area, on both sides of which the surface is obliquely flattened; under surface concave around the peristome. The apex is slightly forward of the center.

The ambulacral areas are narrow throughout their whole length; dorsal portions petaloid; petals narrow, rather short, partly closing, the posterior pair slightly longer than the anterior pair which are longer than the odd petal. The poriferous zones are narrow, outer pores oval, inner ones round, pairs of pores conjugate.

The apical system is small, excentric anteriorly, slightly more so than the apex. There are four genital pores, of which the anterior pair are nearer together than the posterior; and there appear to be five very small perforated radial plates. The madreporite is very small and flush with the surface.

The surface of the test is closely set with very small, apparently imperforate tubercles with deep scrobicules. The tubercles are slightly larger on the under surface except along a rather narrow nearly bare median band back of the peristome.

The peristome is excentric anteriorly, beneath the apical system, subpentagonal, transversely elongate, with a well-developed floscelle.

The periproct is small, oval, the greater diameter being vertical; marginal, or slightly supramarginal, beneath a slightly overhanging projection of the keel, at the top of a vertical sulcus which notches the posterior end of the test.

Related forms.—*Echinanthus georgiensis* is quite distinct from all other American echinoids, the notched posterior end and the details of the periproct affording a ready means of separation from all forms which in any way resemble it. Among foreign forms it resembles *Echinanthus subcarinatus* Goldfuss from the Oligocene of Germany but has a less regularly oval outline and a less pronounced posterior rostration.

Locality.—Five miles south of Ellaville, Ga.

Geologic horizon.—Midway formation, lower Eocene.

Collection.—U. S. National Museum (1656836b).

Order ATELOSTOMATA.

Suborder ASTERNATA.

Family CASSIDULIDÆ.

Genus CASSIDULUS Lamarck.

Cassidulus californicus F. M. Anderson.

Plate LXV, figure 2a–b.

Cassidulus californicus F. M. Anderson, 1905, California Acad. Sci. Proc., 3d ser., Geology, vol. 2, No. 2, p. 194, Pl. XIII, figs. 6, 7.
Cassidulus californicus Arnold, 1909, U. S. Geol. Survey Bull. 396, p. 13, 112, Pl. IV, figs. 1, 1a.
Cassidulus californicus Arnold and R. Anderson, 1910, U. S. Geol. Survey Bull. 398, pp. 70, 284, Pl. XXVI, figs. 1, 1a.
Cassidulus californicus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 696.

Description.—As the writer has not been able to obtain possession of any specimens of this species the description of Anderson is given verbatim:

> Test small, elliptical, robust and often somewhat globular; lower surface flattened, or concave, upper surface convex; mouth not central, round, and occupying a position three-fifths of the distance from the anal margin; anal pore terminal; apical star nearly symmetrical, central, on dorsal surface; tuberculation distinct, the tubercles lying within rounded pits. There is a tendency to form shoulder-like expansions on the periphery behind the position of the mouth.

Anderson does not mention a floscelle nor do his figures show one, but the figured specimen of Arnold shows a floscelle distinctly. Arnold's figures also show a test with a suboblong marginal outline and a supramarginal periproct, apparently transverse, beneath an overhanging expansion of the test. Arnold's form, here refigured, was 21 millimeters long.

Locality.—Four miles west-northwest of Coalinga, Cal.

Geologic horizon.—Tejon formation, upper Eocene.

Collections.—California Academy of Natural Sciences; U. S. National Museum (165664).

Cassidulus (Rhynchopygus?) holmesi Twitchell, n. sp.

Plate LXV, figures 3a–d.

Determinative characters.—Test small, broadly oval, slightly truncated at the posterior end; upper surface convex, sides and ends rounded and inflated; under surface concave around the peristome. Ambulacral areas narrow, petaloid; petals nearly equal, partly open. Apex central; apical system excentric anteriorly. Peristome excentric anteriorly, pentagonal, longitudinally elongate, with a floscelle. Periproct elliptical, transverse, supramarginal; located in a rather deep, oval indentation whose edges are almost flush with the posterior surface of the test.

Dimensions.—Length 25 millimeters; width 22.5 millimeters; height 14 millimeters.

Description.—Only a single specimen of this interesting species is known to the writer. It was found in the F. S. Holmes collection, now owned by the American Museum of Natural History, and as it was probably collected by Holmes is named in his honor. The test is small, broadly oval, being but slightly longer than it is broad, slightly truncated at the posterior end. The upper surface is regularly convex, somewhat elevated, sides and ends sloping nearly uniformly to the rounded and inflated margin; under surface tumid around the margin, concave around the peristome; apex central.

The ambulacral areas are rather narrow, dorsal portions petaloid; petals nearly equal in length, the posterior pair being but slightly longer than the others, nearly closing at the ends. The poriferous zones are rather broad, outer row of pores oval, inner row round, pairs of pores conjugate.

The surface of the test is closely set with small tubercles in deep scrobicules, which are larger on the under surface except along a cribriform median band.

The apical system is excentric anteriorly. There are four genital pores of which the anterior pair are nearer together than the posterior. No further details can be made out on the single specimen known.

The peristome is excentric anteriorly, immediately beneath the apical system, pentagonal, longitudinally elongate, with a floscelle.

The periproct is elliptical, transverse, supramarginal, located in a rather deep, oval indentation at the top of the slight posterior truncation. The edges of the indentation are almost even with the posterior margin. Below the periproct a vaguely defined, broad, shallow groove extends downward across the margin.

Related forms.—*Cassidulus holmesi* is not closely allied to any American form. Its broadly oval and uniformly convex form, nearly equal ambulacral petals, and the details of its periproct and peristome readily distinguish it. It does not appear to be closely related to any foreign form.

Locality.—Santee River (?), S. C.

Geologic horizon.—Probably in the McBean formation of Claiborne group, middle Eocene. The matrix is a fine-grained greensand such as is known to occur on Santee River.

Collection.—American Museum of Natural History.

Cassidulus (Rhynchopygus) lyelli (Conrad).

Plate LXV, figures 4a–d.

Nucleolites lyelli Conrad, 1850, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 2, p. 40, fig. 14.
Cassidulus lyelli Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 75.
Pygorhynchus lyelli Cotteau, 1888, Paléontologie française, Échinides éocènes, vol. 1, p. 550.
Nucleolites lyelli Boyle, 1893, U. S. Geol. Survey Bull. 102, p. 200.
Pygorhynchus lyelli Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 696.

Determinative characters.—Test low, oval in marginal outline, truncated at the posterior end; upper surface convex, depressed; under surface slightly concave around the peristome; apex slightly excentric posteriorly. Ambulacral areas narrow, dorsal portions petaloid; petals long, elliptical. Poriferous zones narrow; pores subequal; interporiferous areas rather wide. Apical system excentric anteriorly. Peristome excentric anteriorly, beneath the apical system, subpentagonal to subtriangular, with a floscelle. Periproct suboblong to dumbbell shaped, transversely elongate, supramarginal, nearly flush with the truncated posterior face of the test; with an overhanging rostrum.

Dimensions.—Length 33 millimeters; width 28 millimeters; height 15 millimeters.

Description.—The present whereabouts of the type of Conrad's *Cassidulus lyelli* is unknown; but as the present species answers so well to Conrad's description and drawings and as it came from about the same locality, it is thought highly probable that it is the same. However, as only a single somewhat imperfect specimen is known, further collecting may show that it is not Conrad's form, in which case the present species will have to receive a new name. The test is regularly oval or subelliptical in marginal outline, vertically truncated at the posterior end. The upper surface is low, almost uniformly convex, depressed, slightly more elevated posteriorly than anteriorly; under surface slightly convex posteriorly, faintly concave around the peristome. The apex is slightly excentric posteriorly.

The ambulacral areas are narrow, dorsal portions petaloid, petals long, symmetrically elliptical, somewhat open at the ends, the posterior pair longer than the others, which are nearly equal in length. The poriferous zones are narrow, similar; pores subequal in size, outer row oval, inner row round, pairs of pores conjugate; interporiferous areas relatively rather wide.

The surface of the test is closely set with small scrobiculate tubercles, which are larger on the under surface. The under surface is poorly preserved on the single specimen obtained; but there appears to have been a median band back of the peristome which was somewhat smoother than the adjacent areas and was more or less pitted.

The apical system is excentric anteriorly, being about three-eighths the length of the test from the anterior end. The details can not be made out, beyond the fact that there are four genital pores of which the anterior pair are nearer together than the posterior.

The peristome is excentric anteriorly, immediately beneath the apical system. It is poorly preserved; but there is enough to show that it is subpentagonal, though approaching a subtriangular form, and surrounded by a somewhat inconspicuous floscelle.

The periproct is subelliptical to suboblong, considerably elongated transversely, supramarginal, at the top of and nearly flush with the vertically truncated posterior surface of the test. The rounded central part of the upper edge extends downward so as to break the elliptical contour of the periproct, and projects slightly beyond the periproct so as to slightly overhang the vaguely defined broad and shallow groove which extends below the periproct across the posterior margin.

Related forms.—*Cassidulus lyelli* is quite distinct from all other representatives of the genus from American strata. Its transversely suboblong periproct and its low regularly oval form readily permit of its identification. It does not appear to be closely related to any foreign form.

Locality.—In Baker County, Ga.

Geologic horizon.—Jackson formation, upper Eocene.

Collection.—Boston Society of Natural History (1552a).

Cassidulus (Rhynchopygus) raveneli Twitchell, n. sp.

Plate LXV, figures 5a–d; Plate LXVI, figures 1a–c, 2a–b.

Pygorhynchus crucifer Ravenel, 1848, Echinidæ, recent and fossil, of South Carolina, p. 4, Pl. II, figs. 9, 10.
Pygorhynchus crucifer Ravenel, 1850, Cat. recent and fossil Echinidæ of South Carolina: Am. Assoc. Adv. Sci. Proc., vol. 3, p. 160.
Ravenelia crucifer McCrady, 1859, Elliott Soc. Nat. Hist. Charleston Proc., vol. 1, pp. 282, 283, no figure.
Pygorhynchus crucifer Agassiz, 1883, Mus. Comp. Zool. Mem., vol. 10, No. 1, p. 91.
non *Nucleolites crucifer* Morton, 1834, Synopsis organic remains Cretaceous, p. 75, Pl. III, fig. 15.
non *Trematopygus crucifer* Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 76.
non *Trematopygus crucifer* Clark, 1893, U. S. Geol. Survey Bull. 97, p. 63.

Determinative characters.—Test hemiellipsoidal, elliptical in marginal outline, truncated at posterior end; upper surface considerably depressed, convex, declining more gently to the ends than to the sides; under surface slightly concave longitudinally. Ambulacra petaloid, the posterior petals longer than the others and bending outward toward their ends. On the under side there is a wide, longitudinal, median band, where the tubercles are replaced by a more or less pitted surface. Apex central; apical system excentric anteriorly. Peristome pentagonal, excentric anteriorly, with a well-defined floscelle. Periproct supramarginal, rather large, elliptical, transverse, concealed beneath an overhanging rostrum at the head of a short, broad sulcus.

Dimensions.—Specimen A (type): Length 40 millimeters; width 29 millimeters; height 14 millimeters. Specimen C: Length 55 millimeters. Largest specimen seen: Length 55 millimeters; width 39 millimeters; height 18 millimeters.

Description.—Dr. Edmund Ravenel, of Grove, S. C., in 1848, in a pamphlet of which but a few copies were printed,[1] gave some good figures of a form which is evidently the same as the one here described. He gave no description and did not regard the form as new; but said it was the same as *Nucleolites crucifer* Morton and placed it in the genus Pygorhynchus. Ravenel was undoubtedly mistaken in regarding his form as the same as that of Morton, for there is hardly more than a superficial resemblance between them. W. B. Clark assigns Morton's form to the genus Trematopygus, whereas the form which Ravenel figured and which is here described for the first time is a Cassidulus of the Rhynchopygus type. However, in view of Ravenel having been the discoverer of the form and in recognition of his interest in and additions to the knowledge of the fossil Echinoidea of South Carolina this interesting species is named after him.

The test of this species is hemiellipsoidal in form, regularly elliptical in marginal outline, and truncated and slightly indented at the posterior end. The upper surface is low, depressed, and rather uniformly convex, though more abruptly so transversely than longitudinally; under surface slightly concave along the longitudinal median area, the concave portion being limited along the sides by the somewhat inferiorly projecting side edges. The apex is central.

[1] The Library of Congress at Washington possesses the copy which was studied by the writer.

The ambulacral areas are petaloid, the petals rather long and narrow, converging toward their extremities, where they remain partly open; the posterior pair longer than the rest and bending outwardly near their extremities; the odd petal shorter than the posterior but slightly longer than the anterior pair. The poriferous zones are rather narrow, but slightly more than half the width of the narrow interporiferous areas; outer row of pores slitlike, inner row round; pairs of pores conjugated by narrow grooves separated by low, easily effaced ridges.

The interambulacral areas are broad; the posterior area slightly inflated from the apex to the periproct, where it projects as an overhanging rostrum. The tubercles on the upper sides of the test are numerous, uniformly small, close together, and with deep scrobicules; the intervening spaces being covered with still smaller granulations. On the under side the tubercles are larger, except along a rather wide, longitudinal, median band, which is free from tubercles but dotted with numerous pits.

The apical system is excentric anteriorly, compact, and consists of four basal plates perforated by large pores, the two anterior pores being slightly nearer together than the posterior; five small radial plates, each perforated by a minute pore; and a large madreporite, which occupies the center of the system.

The peristome is of medium size, pentagonal, excentric anteriorly, directly beneath the apical system, with a well-defined floscelle. The floscelle is composed of five prominent rounded bourrelets with granulated surfaces alternating with five large well-developed phyllodes. In addition to outer rows of pores each phyllode has two inner rows ending in two rather large pores, which are located just between adjacent bourrelets.

The periproct is rather large, elliptical, transversely elongate, supramarginal, and concealed beneath an overhanging rostrum at the head of a broad and rather shallow sulcus, which extends beyond the rostrum to the truncated posterior margin of the test.

Related forms.—*Cassidulus raveneli* from its size, shape, and details of structure is readily separated from the other representatives of the genus occurring in the American and European Cenozoic deposits. In several features it resembles *Rhynchopygus calderi* d'Archiac and Haime from the Tertiary deposits of India, but it is more depressed and has a more regularly elliptical marginal outline. In a less degree it resembles *Eurhodia morrisii* d'Archiac and Haime, also from the Tertiary deposits of India, but it is more depressed and lacks the very elongated peristome so characteristic of the Indian form. The nearest American form is *Cassidulus depressus*, from which it is readily distinguished by its greater size and the details of its periproct.

Localities.—South Carolina (Ravenel); Santee Canal (figured specimens), S. C.; Rocky Point and Wilmington, N. C.

Geologic horizon.—In North Carolina in the Castle Hayne limestone, upper Eocene or Oligocene. In South Carolina probably in the Cooper marl (upper Eocene) or the upper part of the McBean formation (middle Eocene).

Collections.—American Museum of Natural History (A, B, and C); U. S. National Museum; Johns Hopkins University.

Cassidulus (Rhynchopygus?) patelliformis (Bouvé).

Plate LXVI, figures 3 a–d.

Catopygus patelliformis Bouvé, 1851, Boston Soc. Nat. Hist. Proc., vol. 4, p. 2, text figures.
Cassidulus patelliformis Desor, 1858, Synopsis des échinides fossiles, p. 290.
Cassidulus patelliformis Dujardin and Hupé, 1862, Hist. nat. zoophytes échinodermes, p. 583.
Cassidulus patelliformis Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 75.
Cassidulus patelliformis Conrad, 1866, Smithsonian Misc. Coll., vol. 7, p. 22.
Cassidulus patelliformis Cotteau, 1888, Paléontologie française, Échinides éocènes, vol. 1, p. 521.
Cassidulus patelliformis Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 700.

Determinative characters.—Test elliptical, narrowing and rather pointed posteriorly; upper surface somewhat elevated, convex, elongate-subconical; under surface flat, meeting the upper surface in an angular margin; apex slightly forward of the center. Ambulacral areas narrow, petaloid; petals rather long, the anterior pair shorter than the posterior pair and odd petal

which are nearly equal in length, closing at the ends. Peristome apparently slightly excentric anteriorly. Periproct small, elliptical, transverse, supramarginal, in a shallow indentation close to the posterior end of the test.

Dimensions.—Length 32 millimeters; width 21 millimeters; height 15 millimeters.

Description.—This species was first reported in 1851 by T. T. Bouvé of Boston. The doubt in regard to the generic position of Bouvé's form, which Desor recognized as existing because of a lack of definite knowledge in regard to the inferior surface, is partly resolved by an examination of the type, which though not showing a floscelle does show a cribriform median area on the under surface. A valuable corroboration of this evidence is found in the fact that one specimen of *Cassidulus depressus*, the form most nearly related to the present species, shows a well-defined floscelle. The test of this species is elliptical in marginal outline, narrowing noticeably toward the posterior end. The upper surface is somewhat elevated, convex, elongate-subconical, sloping steeply to the margin, slightly less so posteriorly than on the sides and anteriorly; under surface flat, meeting the sides at the margin in an acute angle; apex slightly forward of the center. The general appearance of the form, as the name given by Bouvé implies, is much like that of a limpet shell such as those of the genus Patella.

The ambulacral areas are narrow, narrower at the ambitus than in the petaloid region; dorsal portions petaloid, the petals rather long, the anterior pair shorter than the posterior pair and odd petal, which are nearly equal in length; petals closing at their extremities. The details of the ambulacra and apical system are not discernible on the specimen.

The peristome is apparently slightly eccentric anteriorly; details can not be made out. The periproct is small, elliptical, transverse, supramarginal; located in a small, shallow, transverse indentation only slightly above the margin and very close to the rather pointed, truncated, posterior end of the test.

The surface of the test is covered with numerous small tubercles, with scrobicules, larger on the under surface except along a rather broad median area back of the peristome where the surface is free from tubercles and more or less cribriform.

Related forms.—No other species of Cassidulus reported from the United States bears any close resemblance to *Cassidulus patelliformis*. It is closely related to *Cassidulus depressus* but can easily be distinguished by its greater size, more elevated and elongated subconical upper surface, more steeply sloping posterior face, and lower placed periproct.

Locality.—Georgia, probably Baker County.

Geographic horizon.—Probably upper Eocene. May be lower Oligocene.

Collection.—Boston Society of Natural History (1558).

Cassidulus (Rhynchopygus) depressus Twitchell, n. sp.

Plate LXVI, figures 4a–e, 5a–b.

Determinative characters.—Test very small, subelliptical, upper surface much depressed, convex, declining gently on the sides, the posterior end sloping more steeply than the anterior; undersurface slightly concave. Apex central; apical system excentric anteriorly. Peristome small, pentagonal, slightly elongate longitudinally, anteriorly excentric, with a well-defined floscelle. Between the peristome and the posterior border there extends a wide, elliptical, cribriform area. Periproct small, elliptical, transverse, situated rather high above the posterior margin, in a shallow indentation.

Dimensions.—Specimen A (type): Length 16 millimeters; width 12 millimeters; height 7 millimeters.

Description.—This small Cassidulus, one of the smallest representatives of the genus occurring in American deposits, has a test which is subelliptical in marginal outline. The upper surface is much depressed, longitudinally convex, declining gently on the sides. The posterior median area, between the apical system and the periproct remains at nearly the same elevation from which the surface slopes steeply to the posterior margin and less steeply to the anterior. The undersurface is nearly flat, or slightly concave longitudinally, meeting the sides at the margin in a somewhat acute angle. The apex is central or subcentral.

The ambulacral areas are obscure on the specimens studied; but are apparently narrow with petaloid dorsal portions. The narrow poriferous zones show an outer row of slitlike pores and an inner row of round pores. The other details can not be made out. The apical system is excentric anteriorly; its details are not discernible.

The peristome is small, pentagonal, slightly elongate longitudinally, anteriorly excentric, beneath the apical system, with a well-defined floscelle having prominent bourrelets and rather extensive rounded phyllodes.

The periproct is small, elliptical, transverse, situated rather high above the posterior margin in an indentation in the test.

The surface of the test is covered with numerous small tubercles, with scrobicules, larger on the under surface. Between the peristome and the posterior border there extends a wide elliptical, cribriform area.

Related forms.—This form is most closely related to *Cassidulus patelliformis* (Bouvé) from which it is readily distinguished by its smaller size, more depressed form, the higher position of its periproct, and the greater relative elevation of the upper surface between the periproct and the apical system. It also resembles *Cassidulus raveneli* but is very much smaller, and its periproct has a less conspicuous overhanging rostrum in a shallower depression. In several respects it resembles *Rhynchopygus pygmæus* Duncan and Sladen from the Tertiary of India, but it is more depressed and much narrower posteriorly.

Locality.—Baker County, Ga.

Geologic horizon.—Probably upper Eocene. May be lower Oligocene.

Collection.—Boston Society of Natural History (1557a, A; 1557b, B).

Cassidulus (Pygorhynchus) conradi Conrad.

Plate LXVII, figures 1a–f.

Catopygus conradi Couper MSS., fid. Conrad.
Catopygus conradi Conrad, 1850, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 2, p. 39, Pl. I, fig. 9.
Cassidulus conradi Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 75.
Cassidulus conradi Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 22.
Catopygus conradi Agassiz, 1883, Mus. Comp. Zoology Mem., vol. 10, No. 1, p. 90.
Cassidulus conradi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 700.

Determinative characters.—Test ovate in marginal outline, broad anteriorly, narrowing abruptly posteriorly; sides and anterior end somewhat flattened, posterior end truncated; upper surface convex, depressed, flattened on top; under surface flattened, slightly concave around the peristome; apex usually forward of the center. Ambulacral areas narrow. Apical system very excentric anteriorly. Peristome excentric anteriorly, less so than the apical system, pentagonal, transversely elongate, with a floscelle. Periproct elliptical, transverse, supramarginal; beneath an overhanging expansion of the test, whose edge is even with the posterior margin.

Dimensions.—Length 41 millimeters; width 35 millimeters; height 23 millimeters.

Description.—This species was first figured in 1850 by Conrad, who also gave a good description of the form. He, however, credits the species to a manuscript description by J. Hamilton Couper and says that the name given was adopted at the particular request of Mr. Couper. The test is ovate in marginal outline, broad anteriorly, narrowing abruptly posteriorly; margin somewhat flattened anteriorly, more so on the sides which are nearly vertical at the ambitus but round over the edges to the upper and lower surfaces, obliquely truncated posteriorly and truncated vertically at the posterior end. The upper surface is convex, depressed, flattened on top, and in the form of a low, rounded ridge above the periproct; undersurface flattened, slightly concave around the peristome and slightly convex posteriorly. The lower edge at the posterior end is somewhat prominent, angular and slightly rostrate. The apex is usually forward of the center, when it is coincident with the apical system; but even then it is only slightly higher than the surface of the posterior interambulacrum, and in some forms the upper surface is so depressed anteriorly as to make the apex excentric posteriorly.

The ambulacral areas are narrow, dorsal portions petaloid; petals long, narrow, and open at their ends, the posterior pair being longer than the others which are nearly equal in length. The poriferous zones are narrow, the adjacent zones of the anterior and posterior paired petals being slightly broader and straighter than the others; pores small, outer row slitlike, inner row round, pairs of pores conjugate.

The apical system is very excentric anteriorly, being located less than a third of the length of the test from the anterior end. There are four genital pores, of which the anterior pair are nearer together than the posterior; and there are five small perforated radial plates. These are the only details that can be made out on the specimens.

The surface of the test is closely set with very small imperforate tubercles with deep scrobicules. The tubercles are slightly larger on the under surface except along a narrow median band back of the peristome, which is free from tubercles, nearly smooth and dotted with numerous very small pits.

The peristome is excentric anteriorly, less so than the apical system, pentagonal, transversely elongate, with a well-defined floscelle.

The periproct is rather large, elliptical, transverse, supramarginal, at the top of the posterior truncation; beneath a rounded, transverse, somewhat protruding expansion of the test whose edge is about even with the truncated posterior margin.

Related forms.—*Cassidulus conradi* is readily distinguished from the other representatives of the genus from American strata. It is most nearly related to *Cassidulus carolinensis*, but can be separated by its more excentric apical system and more transverse peristome and by being narrower posteriorly and less concave around the peristome. Its nearest European ally appears to be *Pygorhynchus maveri* de Loriol from the Tertiary of Switzerland, but the latter has both its apical system and peristome less excentric anteriorly and does not have its peristome transversely elongated. *C. conradi* also resembles *Pygorhynchus grignonensis* (Defrance) Agassiz from the Eocene of France, but is narrower posteriorly and has its apical system less excentric anteriorly.

Localities.—Palmyra, Lee County, Ga. (Conrad); Baker County, Ga.

Geologic horizon.—Upper Eocene or lower Oligocene or both. Conrad gave the matrix of the form as white limestone.

Collections.—Academy of Natural Sciences of Philadelphia (1078); Boston Society of Natural History.

Cassidulus (Pygorhynchus) carolinensis Twitchell, n. sp.

Plate LXVII, figures 2a–g.

Determinative characters.—Test thin walled, oval in marginal outline, posterior end truncated; sides and anterior end rounded; upper surface convex, depressed, slightly more elevated posteriorly than anteriorly and with a rather prominent low, rounded ridge above the periproct; under surface flat, concave around the peristome; apex central or slightly excentric posteriorly. Ambulacral areas narrow. A narrow granulated, median band back of the peristome. Apical system excentric anteriorly; madreporite slightly tumid. Peristome excentric anteriorly, directly beneath apical system, pentagonal, with a floscelle. Periproct elliptical, transverse, supramarginal beneath an overhanging expansion of the test, whose edge is even with the posterior margin.

Dimensions.—Length 36 millimeters; width 32 millimeters; height 18 millimeters. This specimen is about a fourth larger than the average.

Description.—This species occurs in large numbers at several localities in North Carolina, notably in association with *Echinolampas appendiculatus*. The test is thin walled, regularly oval in marginal outline, the posterior end vertically truncated. The upper surface is uniformly convex, depressed, sides and anterior end rounded, slightly more elevated posteriorly than anteriorly and in the form of a low rounded ridge above the periproct; under surface flat, tumid near the margin, concave around the peristome. The apex is central, or slightly excentric posteriorly.

The ambulacral areas are narrow, dorsal portions petaloid; the petals long, rather narrow, nearly closing, the posterior pair slightly longer than the others which are nearly equal in length. The poriferous zones are rather narrow, faintly depressed, outer pores oblong, inner ones round, pairs of pores conjugate.

The surface of the test, including the interporiferous areas and the ridges between the pairs of pores, is closely set with small imperforate tubercles set in deep scrobicules. Between the tubercles are minute granules. The tubercles increase in size on the under surface except along a narrow band back of the peristome, which is somewhat smooth but dotted with numerous granulations.

The apical system is excentric anteriorly. There are four genital pores, the anterior pair being nearer together than the posterior; and five perforated radial plates. The madreporite is large, oval and faintly tumid, as are the adjacent portions of the interambulacral areas.

The peristome is somewhat large, pentagonal, excentric anteriorly, directly beneath the apical system, surrounded by a floscelle of which the bourrelets are rather prominent, granulated, and together form a nearly circular ring around the peristome.

The periproct is elliptical, transverse, supramarginal, at the top of the posterior truncation; beneath a rounded, transverse, somewhat protruding expansion of the test, whose edge is just even with the truncated posterior margin.

Related forms.—*Cassidulus carolinensis* is closely related to *C. conradi* and resembles it in a number of features, notably in the details of the periproct; but it is to be separated by its less excentric apical system, by its less transverse peristome with the subcircular ring of bourrelets, by being broader, more rounded and less rostrate posteriorly, and by having a more marked concavity around its peristome. *C. carolinensis* also resembles *C. georgiensis* but is to be distinguished by the concavity around its peristome, its less obtuse and less angular posterior margin, and its lower and less oblique posterior truncation. Among European forms *C. carolinensis* greatly resembles *Pygorhynchus maveri* De Loriol from the Tertiary of Switzerland (more so than does *C. conradi*), but differs in having its periproct higher up on the posterior surface, and in the failure of the expansion of the test over the periproct to protrude noticeably beyond the posterior margin. In a number of features *C. carolinensis* is similar to *Pygorhynchus grignonensis* (Defrance) Agassiz from the Eocene of France, but it can be separated by its more depressed form and the higher relative position of its periproct.

Localities.—Smith Creek (type), Rocky Point, and Wilmington, N. C.

Geologic horizon.—Castle Hayne limestone, upper Eocene or Oligocene.

Collections.—Johns Hopkins University (T 2004); U. S. National Museum.

Cassidulus amygdala Desor.

Cassidulus amygdala Desor, 1858, Synopsis des échinides fossiles, p. lxv.
Cassidulus amygdala Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 22.
Cassidulus amygdala Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 22.

This is a Swiss species described on page 290 of Desor's Synopsis and erroneously listed by Desor in his table of distribution, page lxv, as among the Eocene Echinodermata of America. Conrad, failing to note the error, also listed the form in his catalogue and check list.

Pygorhynchus rugosus Ravenel.

Pygorhynchus rugosus Ravenel, 1848, Echinidæ, recent and fossil, of South Carolina, p. 4, Pl. II, figs. 7, 8.
Pygorhynchus rugosus Ravenel, 1850, Cat. recent and fossil Echinidæ, South Carolina, p. 160.
Pygorhynchus rugosus Agassiz, 1883, Mus. Comp. Zoology Mem., vol. 10, No. 1, p. 91.

Ravenel, in 1848, published in an out of the way pamphlet two poor drawings, unaccompanied by a description, of a form from the Eocene of South Carolina for which he proposed the name *Pygorhynchus rugosus*. The species is not entitled to recognition; and the writer has been unable to locate the type or to recognize the form among the material studied.

Genus BREYNELLA Gregory.

Breynella gregoryi Twitchell, n. sp.

Plate LXVIII, figures 1a–f.

Breynella sp. Gregory, 1891, Geol. Soc. America Bull., vol. 3, p. 104. Nomen nudum.

Determinative characters.—Test suboval in marginal outline, broadest back of the center, narrowing posteriorly, truncated vertically at the posterior end; sides and anterior end rounded; upper surface convex, somewhat elevated, especially along the posterior median area, apex slightly to the rear of the center; under surface rather flat, slightly concave near the peristome. Ambulacral areas narrow, supetaloid; petals rather short, straight, flush, inconspicuous and open at the ends. Apical system very excentric anteriorly. Peristome pentagonal, excentric anteriorly, but somewhat less so than the apical system; with a floscelle. Periproct oblong-oval, longitudinally elongate, supramarginal, at the top of, and flush with the vertical surface of the posterior truncation.

Dimension.—Length 34 millimeters; width 28 millimeters; height 18 millimeters.

Description.—This medium-sized Breynella is the first representative of the genus to be reported from the United States. The specimens here described are probably the same which J. W. Gregory saw at the American Museum of Natural History, and as he first recognized the form as a Breynella it is named in his honor. The test of this species is suboval to subovate in marginal outline, broadest back of the center, narrowing toward the posterior end, which is vertically truncated. The sides are rounded and inflated; the upper surface convex, somewhat elevated, especially along the posterior median area, which, however, gradually declines in the form of a low rounded ridge on approaching the region of the periproct; the under surface rather flat, tumid around the margin, slightly concave near the peristome. The apex is slightly to the rear of the center.

The ambulacral areas narrow, widest at the ambitus, where they are only slightly wider than the petaloid portions; dorsal portions subpetaloid, the petals being rather short, straight, flush, inconspicuous, and open at the ends; the posterior pair slightly longer than the others, which are nearly equal in length. The poriferous zones are rather narrow; outer row of pores oval, inner row round; pairs of pores conjugate.

The apical system is very excentric anteriorly, being situated about one-third the length of the test from the anterior end. Its details are not well shown on the specimens studied; but there are four genital pores of which the anterior pair are nearer together than the posterior.

The peristome is pentagonal, transversely elongate, excentric anteriorly, but somewhat less so than the apical system, with a floscelle. The floscelle is distinct, and the bourrelets are broad and rather prominent; but the phyllodes are not very conspicuous.

The periproct is oblong-oval, longitudinally elongate, supramarginal, at the top of, and nearly flush with the vertical surface of the posterior truncation. A poorly defined shallow groove extends from the periproct down the middle of the posterior truncation.

The surface of the test is closely set with small tubercles, in deep scrobicules, which are somewhat larger on the under surface. There appears to be a very narrow, somewhat pitted, median band behind the peristome which extends along close to the zigzag suture line.

Related forms.—*Breynella gregoryi* resembles in a general way several of the Tertiary species of Cassidulus; but is readily separated by its longitudinally elongate periproct. Its closest American ally is *Echinanthus antillarum* Cotteau, from the Eocene of the West Indies, from which it differs in having its periproct overhung by an expansion of the test. It resembles *E. bonissenti* Cotteau, from the Eocene of France, but is smaller and has its apical system more excentric anteriorly. It also closely resembles *Breynella equizoata* Gregory, from the lower Oligocene of Malta, but may be distinguished by its higher posterior margin and the slightly more anteriorly excentric position of both its apical system and peristome.

Locality.—Santee Canal, S. C.

Geologic horizon.—Probably either the Cooper marl (upper Eocene) or the upper part of the McBean formation (middle Eocene).

Collection.—American Museum of Natural History.

Genus ECHINOLAMPAS Gray.

ECHINOLAMPAS APPENDICULATUS Emmons.

Plate LXVIII, figures 2a–h.

Echinolampas appendiculatus Emmons, 1858, Agriculture Eastern Counties: North Carolina Geol. Survey Rept., p. 307, figs. 240, 241.

Echinolampas appendiculatus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 697.

Determinative characters.—Test suboval to subovate in marginal outline, broad and rounded anteriorly, narrowing in nearly straight lines to the pointed, obliquely truncated posterior end; sides and anterior end rounded and inflated. The upper surface convex, depressed, and usually rather flat on top, with a tumid, rounded ridge over the periproct; under surface very tumid for a wide area around the margin, slightly concave near the peristome. Apex central or subcentral. Ambulacral areas narrow, dorsal portions petaloid; petals narrow, some with poriferous zones unequal in length. Apical system excentric anteriorly. Peristome large, elliptical, transverse, excentric anteriorly, with an inconspicuous floscelle. Periproct large, subelliptical, inframarginal, beneath the protruding posterior ridge.

Dimensions.—The figured form, which is about average size, gave length 33 millimeters; width 28 millimeters; height 17 millimeters. The largest specimen gave length 48 millimeters; width 42 millimeters; height 23 millimeters.

Description.—This species was described and figured by Emmons in 1858. It appears to be limited to North Carolina, where it is often found in association with *Cassidulus carolinensis*. In actual number of specimens it is the most abundant of the Cenozoic Cassiduloidea occurring in the United States, the writer having had more than 300 specimens available for study. The writer has also had the privilege of studying Emmons's type, which is in the collection of Williams College; and as a result has determined that in applying the name "*appendiculatus*" to the species based upon the "subcordate sculptured plate with a pentagonal opening, in the center of which there is a pore" which was said to occupy the apical disk, Emmons made a curious mistake. His type does show a plate of some such character as he described but it is evidently foreign to the test, probably a fragment of some other fossil—possibly the plate of some cidaroid form—which has by accident become cemented to the test in the neighborhood of the apical system. Emmons's type is the only one of the 300 specimens examined by the writer which possesses any such plate. Furthermore, it is difficult to conceive of any possible function for such an appendix to an echinoid test. This species is somewhat variable in minor details, but its broad characteristics are quite uniform and easily distinguished. The test is thin walled, depressed-ovoid in general form; marginal outline suboval to subovate, rounded anteriorly, broadening back of the middle, then rapidly narrowing in almost straight, converging lines to the rather pointed, somewhat rostrate posterior end; margin very round and highly inflated, less so along the narrowing part on both sides of the posterior end, and downwardly and anteriorly truncated at the posterior end. The upper surface is usually rather low, regularly convex, depressed, rather flat on top and in the form of a tumid rounded ridge over the periproct; though occasional specimens are moderately elevated, and somewhat ridged along the whole longitudinal median area; under surface very tumid for a wide area around the margin, slightly concave near the peristome. The apex is central or subcentral.

The ambulacral areas are narrow, dorsal portions petaloid; petals narrow, rather long, varying somewhat in details on the same specimen and from specimen to specimen, the posterior pair usually slightly longer than the anterior three, which are nearly equal in length, partly open at their extremities. The poriferous zones are narrow, flush, the inner zones of the posterior petals slightly shorter than the outer zones, and in a less degree the anterior zones of the anterior paired petals shorter than the posterior zones; outer row of pores oval, inner row round; pairs of pores conjugate, the ridges between the pairs of pores prominent and ornamented with a row of granules.

The surface of the test is highly ornamented. There are numerous small tubercles in wide, deep scrobicules. On the under surface the scrobicules are more numerous, different in size and

shape and closer together; on the upper surface they are more scattered and in granulated rings between which the surface is dotted with numerous small pits.

The apical system is excentric anteriorly and consists of four perforated basal plates, the anterior genital pores being closer together than the posterior, five small perforated radial plates, and a large, central, granulated, faintly tumid madreporite.

The peristome is rather large, regularly elliptical, transverse, excentric anteriorly, though slightly less so than the apical system, surrounded by an inconspicuous floscelle with straight feeble phyllodes and faintly defined, slightly tumid bourrelets.

The periproct is rather large, irregularly elliptical, the upper edge being less convex than the lower edge and constituting the extreme protruding posterior end of the test, inframarginal, beneath the overhanging rounded ridge of the posterior upper surface and level with the downwardly oblique truncation of the posterior margin.

Related forms.—*Echinolampas appendiculatus* is not closely allied to any other American species. It is easily distinguished from *E. aldrichi*, the only other representative of the genus yet reported from the United States. It resembles rather closely *Echinolampas francei* Desor from the Eocene of France but differs in being relatively broader and in having a more regularly elliptical peristome.

Localities.—Newbern, (Emmons), Rocky Point (figured form), Smith Creek, and Wilmington, N. C.

Geologic horizon.—Castle Hayne limestone, upper Eocene or Oligocene.

Collections.—Williams College; U. S. National Museum (138017); Johns Hopkins University.

Suborder STERNATA.

Family SPATANGIDÆ.

Genus HEMIPATAGUS Desor.

HEMIPATAGUS ARGUTUS Clark, n. sp.

Plate LXIX, figures 1a–d.

Determinative characters.—Test small, cordiform, depressed, highest just back of posterior truncation, nearly as broad as long, nearly flat below, with broad anterior sulcus. Ambulacra nearly flush, with slightly depressed poriferous avenues. Interambulacra are broad, the paired area with several widely scattered rather large, crenulate and perforate tubercles, with deep areolas giving the surface an irregularly pitted appearance. The lower flat surface has many tubercles of similar character especially on the sides near the ambitus. The tubercles are much worn on both the upper and lower surfaces of the specimen.

Description.—The single specimen of this very beautiful form has a small test, cordiform in outline, somewhat depressed and nearly as broad as long. The upper surface is flattened anteriorly and elevated posteriorly just back of the posterior truncation. A broad anterior sulcus crosses the ambitus. The lower surface is nearly flat.

The ambulacra are nearly flush, the poriferous avenues being slightly depressed, subpetaloidal, the anterior pair being shorter than the posterior.

The interambulacra are broad, the paired areas with several widely scattered rather large, crenulated and perforate tubercles, with deep areolas giving the surface an irregularly pitted appearance. The lower flat surface has many tubercles of similar character especially on the sides near the ambitus. The tubercles are much worn on both the upper and lower surfaces of the specimen.

The apical system is indistinct. The peristome is large and oval in outline. The periproct is large and supramarginal in position.

Related forms.—The species is similar in certain features to *H. subrostratus* but is wider anteriorly, has a more cordate form, and is higher posteriorly.

Locality.—Enterprise, Clarke County, Miss.

Geologic horizon.—Claiborne group, middle Eocene.

Collection.—U. S. National Museum (141107).

Hemipatagus subrostratus Clark, n. sp.

Plate LXIX, figures 2a–b.

Determinative characters.—Test medium size, subcordiform, only slightly higher posteriorly, longer than wide, nearly flat below, with broad anterior sulcus. Ambulacra broad, somewhat depressed, the poriferous avenues subpetaloidal, the anterior pair longer than the posterior. Interambulacra with a number of large scattered tubercles in the paired areas with deep areolas, crenulate and perforate.

Dimensions.—Length 33 millimeters; width 29 millimeters; height 14 millimeters.

Description.—The single specimen of this species is much damaged on the lower surface and posterior end, neither the peristome nor periproct being preserved. The test is of medium size, subcordiform, only slightly higher on the posterior part than on the forward part of the upper surface. It is longer than wide, the widest portion being only slightly forward of the middle of the test. A broad anterior sulcus extends from the apex over the ambitus. The lower surface is nearly flat.

The ambulacra are nearly flush, somewhat depressed, the poriferous avenues subpetaloidal, the anterior pair longer than the posterior. The pores are oval and connected by prominent furrows.

The interambulacra are somewhat elevated with a number of large, scattered tubercles in the paired areas. The tubercles have deep areolas, and are crenulate and perforate.

Related forms.—This species is similar to *H. argutus* but is narrower anteriorly, has a less cordate form, and is lower posteriorly.

Locality.—Wilmington, N. C.

Geologic horizon.—Castle Hayne limestone, upper Eocene or Oligocene.

Collection.—U. S. National Museum (164652).

Genus SCHIZASTER Agassiz.

Schizaster lecontei Merriam.

Plate LXIX, figures 3a–b.

Schizaster (?) sp. Merriam, 1897, Jour. Geology, vol. 5, p. 773.
Schizaster lecontei Merriam, 1899, California Acad. Sci. Proc., 3d ser., Geology, vol. 1, pp. 164, 165, Pl. XX, figs. 1, 1a.
Schizaster lecontei Stefanini, 1911, Soc. Geol. italiana Boll., vol. 30, p. 697.

Determinative characters.—Test small, cordiform, elevated, with a sharp ridge from apical system to posterior truncation. Apex posterior to center of test. Ambulacra broad, depressed, petals of posterior pair less than half the length of anterior. Peripetalous fasciole distinct. Apical system posterior to center. Peristome well forward. Periproct high on truncated posterior surface.

Dimensions.—Length 20 to 23 millimeters.

Description.—The specimens of this species are preserved only as impressions or casts, badly crushed. The test is small, cordiform, upper surface much elevated, with a sharp ridge running from the apical system to the posterior truncated surface. A broad groove notches the anterior margin.

The ambulacra are broad, the poriferous zones depressed, petaloidal, the petals of the posterior pair very short, less than half the length of the anterior, sometimes almost circular in outline. Pores elongated, apparently yoked.

The interambulacra broad. Tubercles larger on the lower surface. Peripetalous fasciole quite distinct on one specimen. Traces of what appears to be the lateral fasciole have been seen beneath the periproct.

Apical system excentric, posterior, anterior to the summit.

Peristome well forward, broad two-lipped. Periproct high upon the truncated posterior end.

Merriam says: "Numerous large spines much like those of Schizaster have been found at one locality, but if they belong to this genus at all they were probably derived from another and much larger species."

Locality.—Contra Costa County, Cal.

Geologic horizon.—Martinez and Tejon formations, Eocene.

Collection.—University of California.

Schizaster armiger Clark, n. sp.

Plate LXX, figures 1a–d.

Determinative characters.—Test rather large, cordiform, depressed upper surface slopes at first rapidly then more slowly from anterior margin to apical system, beyond which an elevated sharp ridge continues to the truncated posterior margin. Ambulacra in broad deep furrows, the paired ambulacra in moderately sunken petals, the anterolateral being about one and one-half times as long as the posterolateral. Peripetalous and lateral fascioles distinct.

Dimensions.—Length 53 millimeters; width 46 millimeters; height 22 millimeters.

Description.—This species has a test of moderately large size, much depressed and clearly cordiform in marginal outline. The upper surface slopes at first rapidly from a sharp anterior margin to near the apical system when it becomes nearly flat for a short distance. Beyond the apical system a sharp elevated ridge highest near the middle point continuous on to the truncated posterior margin.

The ambulacra are broad, the single anterior ambulacrum being situated in a deep broad groove that deeply indents the anterior margin. The paired ambulacra have broad deep petals, the anterolateral being somewhat over one and a half times as long as the posterolateral.

The interambulacra are more or less flat, slightly gibbous, the posterior much elevated forming a sharp ridge. The surface is thickly covered with small perforate tubercles. The peripetalous and lateral fascioles are very distinct.

The peristome is near the anterior margin in a shallow depression. The periproct is high on truncated posterior margin.

Locality.—Cocoa post office, Choctaw County, Ala.

Geologic horizon.—St. Stephens limestone (lower part), upper Eocene.

Collection.—U. S. National Museum (141104).

Schizaster sp.

Plate LXX, figure 2.

Fragment of spatangoid test, Clark, 1901, Maryland Geol. Survey, Eocene, p. 232, Pl. LXI, fig. 1.

Description.—A fragment of a spatangoid test found among the Eocene materials collected at Evergreen, Va., apparently belongs to the genus Schizaster, to which it is here referred. A portion of an ambulacrum with the adjacent portion of an interambulacrum, showing many characteristic features, is preserved. The ambulacrum, probably one of the anterolateral pair, is petaloidal, the petal sunken and rather narrow. The interambulacrum is somewhat gibbous and has preserved a part of a peripetalous fasciole.

Locality.—Evergreen, Va.

Geologic horizon.—Nanjemoy formation, middle Eocene.

Collection.—Johns Hopkins University (T 2001).

Genus LINTHIA Merian.

Linthia wilmingtonensis Clark, n. sp.

Plate LXX, figures 3a–c.

Determinative characters.—Test large, cordiform, gibbous above, nearly flat below, ambulacra wide, anterior in deep groove, anterolateral with petals in long deep grooves, posterolateral with petals about one-half the length of the anterolateral and also deeply sunken. Inter-

ambulacra wide, prominent, and covered with numerous small tubercles. Peristome in prominent depression.

Dimensions.—Length 56 millimeters; width 55 millimeters; height 34 millimeters.

Description.—This relatively large form has an elevated, gibbous upper surface and a nearly flat lower surface except for the peristome depression. It is cordiform in marginal outline about as wide as long and rounded laterally.

The ambulacra are wide, the single anterior ambulacrum being situated in a deep groove, which deeply indents the margin. The anterolateral paired ambulacra have long, broad ambulacral petals, while those of the posterolateral pair are only about half as long.

The interambulacral plates are covered with small perforated tubercles. The peripetalous and lateral fascioles can be readily traced.

The peristome is in a pronounced depression near the anterior margin. The periproct is not shown on the type form.

Locality.—Wilmington, N. C.

Geologic horizon.—Castle Hayne limestone, upper Eocene or Oligocene.

Collection.—U. S. National Museum (166482).

Linthia alabamensis Clark, n. sp.

Plate LXXI, figures 1a–d, 2a–d.

Determinative characters.—Test small, nearly round, except for groove on anterior margin and slight truncation posteriorly, low, somewhat depressed, the upper surface sloping gradually toward the apex. Ambulacra narrow, not deeply sunken, the posterolateral petals much shorter than the anterolateral. Peristome near anterior margin. Periproct relatively high on narrow truncated posterior margin.

Dimensions.—Large specimen: Length 34 millimeters; width 35 millimeters; height 19 millimeters. Small specimen: Length 22 millimeters; width 22 millimeters; height 14 millimeters.

Description.—The test of this species is small, low, somewhat depressed, nearly round in ambital outline, except for the rather shallow groove on the anterior margin and the slight, narrow truncation on the posterior margin. The upper surface slopes gradually from the anterior margin posteriorly.

The ambulacra are narrow and not deeply sunken. The single anterior ambulacrum is situated in a narrow, rather shallow groove. The anterolateral paired ambulacra have long, narrow, rather shallow petals, and the posterolateral pair are short and shallow.

The interambulacral plates are covered with small perforate tubercles. The peripetalous and lateral fascioles are not easily traced.

The peristome is in a shallow depression near the anterior margin. The periproct is situated relatively high on the narrow truncated posterior margin.

Localities.—Prairie Creek, Wilcox County, Ala.; near Grand Glaise, Jackson County, Ark.

Geologic horizon.—Midway group, lower Eocene.

Collection.—U. S. National Museum (166483, 173371).

Genus EUPATAGUS Agassiz.

Eupatagus carolinensis Clark, n. sp.

Plate LXXI, figures 3a–d, 4.

Determinative characters.—Test medium size, oval, moderately tumid, nearly flat along the median line, with slight keel. Ambulacra depressed, anterior very slightly, paired ambulacra in shallow grooves, long, the anterolateral pair shorter than the posterolateral. Interambulacra slightly tumid. Apical system excentric, well forward. Peristome excentric in front.

Dimensions.—Length 48 millimeters; width 39 millimeters; height 22 millimeters.

Description.—This very beautiful form has a test of moderate size, oval, moderately tumid on the upper surface and sloping up at a low angle along the median line toward the posterior

ridge, which is low. The posterior margin is slightly contracted. The lower surface is nearly flat, with a slight posterior keel.

The ambulacra are broad, the anterior ambulacrum occupying a slight depression and the paired ambulacra slight grooves in the petaloidal portions. The petals are long, the posterolateral being longer than the anterolateral. The pore pairs are rather large and connected by furrows.

The interambulacra are slightly tumid, the tubercles on the lower surface being much larger than on the upper surface.

The apical system is small and situated well forward. The peristome is large, semilunar in shape, and excentric in front. The peripetalous fasciole is clearly defined.

Locality.—Wilmington, N. C.

Geologic horizon.—Castle Hayne limestone, upper Eocene or Oligocene.

Collection.—U. S. National Museum (164674, 166484).

Genus BRISSOPSIS Agassiz.

Brissopsis rimulatus Ravenel.

Brissopsis rimulatus Ravenel, 1848, Echinoidæ, recent and fossil, of South Carolina, p. 4, Pl. II, figs. 3 and 4.
Brissopsis rimulatus Ravenel, 1850, Am. Assoc. Adv. Sci. Proc., vol. 3, p. 160.
Brissopsis rimulatus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 708.

Description.—Ravenel did not describe this species in 1848 when he proposed the name, but he published two very distinctive figures, which should be sufficient to identify the form if material representing the species should be found. No such material was at hand when this monograph was under preparation.

Locality.—South Carolina (Ravenel).

Geologic horizon.—Eocene (?).

Collection.—Unknown.

Genus MACROPNEUSTES Agassiz.

Macropneustes carolinensis Clark, n. sp.

Plate LXXI, figures 5a–d.

Determinative characters.—Test small, elevated, tumid, subpentagonal. Apical system excentric forward. Ambulacra narrow, petaloidal portions in narrow, shallow grooves. Surface of plates covered with numerous tubercles. Peristome about one-third the distance from the anterior to the posterior margin.

Dimensions.—Length 28 millimeters; width 27 millimeters; height 22 millimeters.

Description.—This attractive little form has an elevated test, tumid in form, and subpentagonal in ambital outline. The apex is excentric forward. The margin is rounded. The ambulacra are narrow, the petaloidal portions being elongate in narrow, shallow grooves. The petals are imperfectly closed. The surface of the plates is covered with numerous, irregularly dispersed granules. The peristome is large, excentric, situated about one-third of the distance from the anterior to the posterior margin; irregularly dispersed tubercles. The interambulacra are slightly gibbous above, the margin sharp, and the lower surface nearly flat. The fascioles are rather indistinct.

The peristome is large, semilunar, with large projecting posterior labrum. The periproct is large and low on the imperfectly truncated posterior surface.

Locality.—Wilmington, N. C.

Geologic horizon.—Castle Hayne limestone, upper Eocene or Oligocene.

Collection.—U. S. National Museum (164651).

Macropneustes mortoni (Conrad).

Plate LXXII, figures 1a–d.

Holaster mortoni Conrad, 1850, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 2, p. 40, Pl. I, fig. 10.
Holaster mortoni Boyle, 1893, U. S. Geol. Survey Bull. 102, p. 150.
Macropneustes mortoni Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 700.

Determinative characters.—Test large, elevated, tumid, slightly cordiform, nearly round, apex excentric forward. Ambulacra broad, petaloidal portions elongate, in very shallow depressions, nearly flush. Surface of both ambulacral and interambulacral plates outside the petals covered with numerous irregularly dispersed tubercles. Peristome forward about one-third the distance from the anterior to the posterior margin. Periproct large, short distance above margin.

Dimensions.—Length 84 millimeters; width 86 millimeters; height 52 millimeters.

Description.—The test of the species is large, elevated, and tumid. It is slightly cordiform in ambital outline, nearly round but for the slight anterior groove and the ill-defined posterior truncation. The apical system is excentric forward, the high upper surface giving the test a somewhat subconical form.

The ambulacra are broad, the petaloidal portions elongate, nearly flush in very shallow depressions that reach far down the sloping sides.

The petals of the ambulacra outside the petaloidal portions of the ambulacra and the interambulacra are covered with numerous irregularly dispersed tubercles.

The peristome is large, excentric forward, situated about one-third of the distance from the anterior to the posterior margin. The periproct is large and situated a short distance above the margin.

Localities.—Palmyra, Lee County, Ga. (type); Fail, Choctaw County, Ala. (figured specimen).

Geologic horizon.—Jackson formation (upper Eocene) and Vicksburg formation (lower Oligocene).

Collection.—U. S. National Museum (146468).

Genus SARSELLA Pomel.

Sarsella gregoryi Clark, n. sp.

Plate LXXII, figures 2a–d.

Sarsella sp. Gregory, 1892.

Determinative characters.—Test small, cordiform, depressed. Apical system nearly central. Ambulacra very diverse anterior in broad deep group, petaloidal portions of paired ambulacra slightly sunken, the posterolateral more than the anterolateral. Several large, irregularly dispersed tubercles crenulate and perforate on the interambulacra. Peristome semilunar. Periproct high on posterior truncation.

Dimensions.—Length 18.5 millimeters; width 17.5 millimeters; height 9 millimeters.

Description.—This small form was noted by Gregory in his cursory examination of American echinoids when in America in 1891 and was referred to the genus Sarsella. The test is small cordiform in ambital outline, depressed, only slightly higher on the posterior portion of the upper surface than the anterior. The under surface is nearly flat.

The ambulacra are very diverse. The anterior ambulacrum is situated in a broad deep groove. The paired ambulacra have diverse slightly sunken petaloidal areas, the petals of the posterolateral pair being broader and shorter and closed below while those of the anterolateral pair are only imperfectly closed.

The surface of the interambulacral plates bears a number of irregularly dispersed large crenulate and perforate tubercles. They are confined to the paired interambulacra.

The apical system is small. The perforations in the four genitals are distinct on the type specimen.

The peristome is large, semilunar, and distinctly excentric forward. The periproct is large, high on the posterior truncation.

Locality.—Santee Canal, S. C.

Geologic horizon.—Santee marl member of McBean formation, of Claiborne group, middle Eocene.

Collection.—American Museum of Natural History.

Spatangus? pachecoensis (Pack).

Spatangus ? pachecoensis Pack, 1909, Univ. California Dept. Geology Bull., vol. 5, No. 18, p. 276, Pl. XXIII, figs. 4, 5.
Spatangus ? pachecoensis Lambert, 1910, Rev. crit. paléozoologie, 4e année, No. 1, p. 55.
Spatangus ? pachecoensis Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 705.

Description.—The species was established by Pack on casts of poorly preserved fragments. It apparently belongs to the Spatangidæ, but its generic relations can not be determined. Lambert, on the other hand, positively refers it to the Scutellidæ and considers the material too fragmentary for specific description.

Locality.—Northwest of Pacheco, Contra Costa County, Cal.

Geologic horizon.—Tejon formation, upper Eocene.

Collection.—University of California.

OLIGOCENE ECHINODERMATA.

Class ECHINOIDEA.

Subclass REGULARIA ENDOBRANCHIATA.

Order CIDAROIDEA.

Family CIDARIDÆ.

Genus CIDARIS Leske.

CIDARIS MORTONI Conrad.

Plate LXXIII, figure 1.

Cidaris mortoni Conrad, 1850, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 2, p. 40, Pl. I, fig. 13.
? Cidaris sp. Bouvé, 1851, Boston Soc. Nat. History Proc., vol. 4, p. 3.
Cidaris mortoni Cotteau, 1892, Paléontologie française, Échinides éocènes, p. 449.
Cidaris mortoni, Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 698.

Description.—The fragment of a Cidaris test, which is here figured and referred to *Cidaris mortoni*, has all of the essential characteristics of the form figured and briefly described by Conrad. The species is large, globose, and circular in ambital outline. The ambulacra are straight, the pore openings round and somewhat distinct. The interambulacra are composed of large plates, each bearing a large perforate and apparently uncrenulate tubercle.

Localities.—Near Palmyra, Lee County, Ga. (type); Baker County, Ga. (figured specimen).

Geologic horizon.—Vicksburg formation, lower Oligocene.

Collection.—Boston Society of Natural History (1555).

CIDARIS SMITHI Clark, n. sp.

Plate LXXIII, figures 2a–c, 3.

Determinative characters.—Test medium size, moderately tall, subcircular in ambital outline. Ambulacra narrow, slightly flexuous. Interambulacra broad, each with two rows of primary tubercles perforate and crenulate, the areola surrounded by a row of secondary tubercles. Miliary space small.

Dimensions.—Diameter 35 millimeters; height 24 millimeters.

Description.—The test of this species is of medium size, moderately tall, and subcircular in ambital outline.

The ambulacra are narrow, slightly flexuous, the poriferous zones separated by four rows of granules at the ambitus, which become reduced to two rows both above and below.

The interambulacra are wide, rather more than three times the width of the ambulacra. Each plate bears a large primary tubercle which is perforate and crenulate and has a medium-sized areola surrounded by a row of granules. The relatively narrow miliary space is thickly covered with tubercles.

A large tubercle was found with the test that probably belongs to the same species. Certain Cidaris spines found at the Central Salt Works, Clarke County, Ala., may represent the same species.

Locality.—The Rocks, Clarke County, Ala.

Geologic horizon.—St. Stephens limestone (upper portion), lower Oligocene.

Collection.—Alabama Geological Survey.

Cidaris georgiana Clark, n. sp.

Plate LXXIII, figure 4.

Determinative characters.—Test moderately high, subcircular, medium size. Ambulacra wide, with large primary tubercle on each plate, the tubercles on contiguous plates closely approximate, wide miliary space between the rows of tubercles.

Dimensions.—Diameter 38 (?) millimeters; height 25 (?) millimeters.

Description.—The test of this species is only partly preserved. It shows, however, the chief determinative characters. It is evidently unlike any other form hitherto described. The test is of medium size, moderately high, and subcircular in ambital outline. The full height and diameter can not be with certainty determined. The ambulacra are rather broad and straight, with four rows of granules between the poriferous zones.

Locality.—Muckafoonee Creek, Ga.

Geologic horizon.—Vicksburg formation, lower Oligocene.

Collection.—U. S. National Museum (166485).

Cidaris branneri Arnold.

Plate LXXIII, figure 5.

Cidaris branneri, Arnold, 1903, U. S. Nat. Mus. Proc., vol. 29, pp. 363, 364, Pl. XXXIII, fig. 5.
Cidaris branneri Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 698.

Description.—Arnold says:

> Test unknown. Spines, long, slender, circular in cross section, attaining a length of at least 25 millimeters and a diameter of over 2 millimeters. Surface of spine smooth for about one-fifth its length from the base; above this it is ornamented by ten longitudinal rows of elongated nodes or granules which are barely connected near the smooth portion, but which partake more and more of the character of nodose ribs toward the distal end; the last one-fifth of the spine is ornamented by five prominent, slightly nodose ribs; the extreme end is blunt and rounded; collar at base only faintly developed.
>
> The spines of this species are easily distinguishable from those of *C. merriami*, new species, from the Eocene, by their smaller size, fewer but much more prominently nodose longitudinal ribs, and smooth basal portion. No complete spine of *C. merriami* was obtained, so that the smooth basal section may possibly be a characteristic of this latter species as well as of *C. branneri*.

Dimensions.—Length 20 millimeters; diameter, basal end 2.2 millimeters, distal end 1.1 millimeters.

Localities.—Santa Cruz quadrangle, Santa Cruz County, locality No. 109 on Bear Creek, 4 miles above its confluence with the San Lorenzo River, Cal.

Geologic horizon.—San Lorenzo formation, upper Oligocene.

Collection.—U. S. National Museum (1056).

Subclass REGULARIA ECTOBRANCHIATA.

Order DIADEMOIDEA.

Suborder ARBACINA.

Family ARBACIIDÆ.

Genus CŒLOPLEURUS Agassiz.

Cœlopleurus aldrichi Clark, n. sp.

Plate LXXIII, figures 6a–b, 7a–c.

Determinative characters.—Test large, subpentagonal, tumid at ambitus, depressed above, nearly flat below. Ambulacra narrow, the two rows of primary tubercles becoming very small toward the apex; poriferous zones narrow and straight, the pore pairs uniserial. Interambulacra wide, each with several rows of large primary tubercles at ambitus reduced to two around peristome and on upper surface, leaving wide median area above. Tubercles with flat areolas and large imperforate mamelons. Peristome with very slight branchial incisions.

Dimensions.—Specimen A: Diameter 38 millimeters; height 20 millimeters. Specimen B: Diameter 28 millimeters; height 12 millimeters.

Description.—The species is characterized by a rather large test, with subpentagonal outline. It is tumid at the ambitus and depressed on the upper surface. It is nearly flat below. The ambulacra are narrow, each bearing two rows of primary tubercles that diminish rapidly in size from the ambitus toward the apex. The poriferous zones are narrow, the pore pairs being uniserial and somewhat crowded toward the apex. The interambulacra are wide with several rows of primary tubercles at the ambitus which become reduced to two toward the peristome and above the ambitus, where a broad median area devoid of tubercles occurs. The peristome is small with slight branchial incisions.

The several specimens examined are much broken and the surfaces much worn.

Locality.—Perdue Hill, Ala.

Geologic horizon.—St. Stephens limestone (upper portion), lower Oligocene.

Collection.—U. S. National Museum (T. H. Aldrich).

Suborder DIADEMINA.

Family CYPHOSOMATIDÆ.

Genus GAGARIA Duncan.

GAGARIA AMERICANA Clark, n. sp.

Plate LXXIII, figures 8a–b.

Determinative characters.—Test small, circular, tumid, subhemispherical, concave below. Ambulacra narrow, each with two rows of small primary tubercles, perforate and crenulate; each compound plate with three pairs of pores. Interambulacra wide, each with two rows of primary tubercles. Apical system large, flush.

Dimensions.—Diameter 14 millimeters; height 8 millimeters.

Description.—This beautiful form has a very small test, with a circular ambital outline. It is tumid, subhemispherical, rather depressed above, concave below. The ambulacra are narrow, each area provided with two rows of perforate and crenulate primary tubercles which are longest at the ambitus and reach to the apical system, gradually diminishing in size. The poriferous zones are narrow, the pore pairs being three in number on each compound plate. The interambulacra are broad, each carrying two rows of primary tubercles similar to the ambulacra between which are many small secondaries and granules. The apical system is large and flush.

This species is based on a single specimen, the peristomial region of which is much damaged.

Locality.—The Rocks, Clarke County, Ala.

Geologic horizon.—St. Stephens limestone (upper portion), lower Oligocene.

Collection.—U. S. National Museum (T. H. Aldrich).

Suborder ECHININA.

Family TRIPLECHINIDÆ.

Genus ECHINUS Linné.

ECHINUS? sp.

Echinus sp. Cunningham, 1895, Am. Micr. Jour., vol. 16, pp. 193–196, figs.

Description.—Small spines and fragments of plates are figured by Cunningham from "calcareous marl" in Clarke County, Miss., and referred to the genus Echinus. It is quite impossible to determine definitely the generic relations of these forms.

Locality.—Red Bluff station, Chickasawhay River, Clarke County, Miss.

Geologic horizon.—Vicksburg limestone, lower Oligocene

Collection.—K. M. Cunningham, Mobile, Ala.

Subclass IRREGULARIA.

Order GNATHOSTOMATA.

Suborder CLYPEASTRINA.

Family FIBULARIIDÆ.

Genus ECHINOCYAMUS Phelsum.

Echinocyamus vaughani Twitchell, n. sp.

Plate LXXIV, figures 1a–d.

Determinative characters.—Test very small, though larger than related American species, thick walled, almost regularly egg shaped, though elongated longitudinally, about twice as long as broad. Upper surface elevated, both upper and lower surfaces flattened along the longitudinal median areas. Apical system anteriorly excentric, with four medium-sized genital pores. Petals relatively short and petaloidal area smaller than in related forms. Peristome relatively large, central, slightly depressed; periproct very small, close to peristome.

Dimensions.—Length, 8 millimeters; width, 4 millimeters; height, 4 millimeters.

Description.—This species is founded upon a specimen collected in Georgia by T. Wayland Vaughan, of the United States Geological Survey, in whose honor it is named. The test, though actually very small, is larger than in the other American representatives of the genus. The test is thick walled, elongate egg shaped in general form, elongate subelliptical to elongate subovate in marginal outline, somewhat pointed anteriorly, about twice as long as broad. The upper surface is high (the height of the test equalling the breadth) and flattened longitudinally; under surface also flattened somewhat along the longitudinal median area and slightly concave around the peristome.

The ambulacral petals are rather well defined, relatively short, thus making the petaloidal area relatively smaller than in allied American forms; petals wide open at ends; poriferous zones diverge in almost straight lines to the ends and consist of small round pores in pairs not distinctly conjugated.

The peristome is relatively large, central, slightly depressed below the surface; periproct very small, about one-third the diameter of the peristome and very close to the peristome.

Related forms.—*E. vaughani* is most closely related to *E. texanus* but can be readily separated by its larger size, less oval marginal outline, more pointed anterior end, greater difference between its longitudinal and transverse diameters, and smaller petaloidal area. *E. vaughani* also resembles *E. parvus* and *E. huxleyanus* but differs from both in having its periproct near the peristome. It also differs from *E. huxleyanus* in being less fragile and less depressed.

Locality.—Little Horseshoe Bend, Flint River, Ga.

Geologic horizon.—Vicksburg formation, lower Oligocene.

Collection.—U. S. National Museum (166486).

Family LAGANIDÆ.

Genus LAGANUM Blainville.

Laganum eldridgei Twitchell, n. sp.

Plate LXXIV, figures 2a–d.

Determinative characters.—Test large, subpentagonal to subdecagonal in marginal outline, longitudinally elongate, truncated at the anterior and posterior ends, more or less undulating along the sides. Whole form greatly depressed, margin thin but thicker than slightly concave submarginal area, petaloidal region tumid. Apex and apical system subcentral. Lower surface flat. Ambulacral petals long, elongate elliptical, extending two-thirds the way to the margin, pointed and closed at the ends; pairs of pores conjugated by very narrow more or less wavy grooves. Ambulacral areas very wide at margin, narrowing rapidly to ends of petals. Peristome moderate in size, subcentral, subpentagonal to subelliptical, transversely elongate.

Ambulacral grooves apparently simple and straight, each groove having a fine line on both sides which rapidly diverge from the main groove. Periproct relatively large, suboval, longitudinally elongate, one-fourth the way from the margin to the peristome.

Dimensions.—Length 96 millimeters; width 75 millimeters; height 10 millimeters.

Description.—The only specimens known of this large and handsome Laganum, the largest representative of the genus from American deposits, were collected in Florida by the late G. H. Eldridge of the United States Geological Survey and the species is therefore named in his honor. The test is large, being 3 to 4 inches long and 2½ to 3 inches wide. In marginal outline it is subpentagonal to decagonal, decidedly longer than broad; margin thin but thicker than the submarginal area, truncated at anterior and posterior ends, more or less undulating along the sides. The whole form is greatly depressed, the upper surface slightly concave around the submarginal area, arising centrally in the form of a low mound which involves the whole petaloidal area; apex subcentral; lower surface flat.

The ambulacral areas are very wide at the margin, being there about four times the width of the interambulacral areas, narrowing rapidly to near the ends of the petals. The petals are long, elliptical in outline, extending two-thirds the way to the margin, pointed and closed at the ends. The anterior pair shorter than the other three, which are subequal in length. The poriferous zones are wide, more than half the width of the rather narrow interporiferous areas, inner row of pores elliptical, outer row very narrowly slitlike, hardly discernible, pairs of pores conjugated by very narrow more or less wavy grooves.

The interambulacral areas are very narrow at the margin, widen rather rapidly to near the ends of the petals, and narrow again toward the apical region. The whole test is closely set with very small tubercles, among which are scattered at irregular distances some larger ones in deep scrobicules.

The apical system is subcentral, at the summit of the tumid area. There are four large genital pores, of which the anterior pair are set closer together than the posterior pair. No other details could be made out on the specimens.

The peristome is of moderate size, subcentral, slightly to the rear of the apical system, subpentagonal to subelliptical, transversely elongate. The details of the ambulacral grooves could not be made out satisfactorily on the specimens studied. As they leave the peristome there appears to be a single straight groove on each side of which are two fine lines which rapidly diverge from the main groove. These side lines may be the boundary lines of what on better preserved specimens would prove to be finely granulated areas, thus forming a peristomial star.

The periproct is relatively large, about half the size of the peristome, suboval, longitudinally elongate, situated about one-fourth the way from the margin to the peristome.

Related forms.—*L. eldridgei* is readily distinguished from all other American forms. It closely resembles *L. elongatum* Agassiz,[1] whose origin is unknown and which is not even stated to be fossil, being very similar in size, general form, and marginal outline, but differs from it in having a suboval instead of circular periproct, placed a little farther from the posterior margin.

Locality.—Suwanee River, Fla.

Geologic horizon.—Vicksburg group, lower Oligocene.

Collection.—U. S. National Museum (164683).

Laganum archerensis Twitchell, n. sp.

Plate LXXV, figures 1a–d.

Determinative characters.—Test small, subpentagonal to subdecagonal in marginal outline. General form subdiscoidal, upper surface very low, nearly parallel with lower surface, with a slightly concave ring involving most of ambulacral petals between the faintly tumid apical region and the notably thickened margin. Highest part of test along anterior margin. Lower surface flat. Ambulacral petals subelliptical, extending two-thirds the way to the margin, ends closed. Apical system slightly excentric anteriorly, with four genital pores set unusually far apart. Peristome small, pentagonal, central; ambulacral grooves simple, straight lines

[1] Monographies d'échinodermes vivans et fossiles, vol. 2, Des scutelles, pp. 117–118, Pl. XXIV, figs. 1–2.

flanked by finely granulated areas, the five constituting a peristomial star. Periproct small, transversely suboval, about one-fourth the way from margin to peristome.

Dimensions.—Length 18 millimeters; width 16 millimeters; height 3.5 millimeters.

Description.—Only a single specimen of this new Laganum has been discovered. It was found at Archer, Fla., whence the name here given. The test is small, subpentagonal or subdecagonal in marginal outline. The whole form is greatly depressed; subdiscoidal, the upper surface being practically parallel with the lower; the apical region faintly tumid, the area between the apical region and the margin slightly concave; the margin notably thickened, slightly less so posteriorly than anteriorly. The lower surface is flat. The highest part of the test is along the surface of the anterior margin, from whence the upper surface slopes gently to the posterior margin, the central tumidity being hardly any higher than the side margins.

The ambulacral petals are subelliptical, extending about two-thirds the way to the margin, the larger part of each petal being depressed so as to form a part of the concave ring on the upper surface, the ends of the petals practically closed. The poriferous zones are rather wide, about half as wide as the interporiferous areas, the proximal ends poorly defined, the inner row of pores round, the outer row slitlike, the pairs of pores conjugated.

The interambulacral areas are very narrow, especially at the margin, where they are hardly more than one-third as wide as the ambulacral areas. The whole surface of the test, including the interporiferous areas and apical region, is covered with small tubercles set in deep scrobicules, which are larger on the under surface.

The apical system is slightly excentric anteriorly at the summit of the faintly tumid central area. There are four large genital pores, set unusually far apart, the anterior pair being nearer together than the posterior pair. The poriferous zones could not be seen to come together at the proximal ends, and the perforations in the radial plates could not be discerned on the specimen.

The peristome is small, central, pentagonal. The ambulacral grooves each consist of a central impressed line and two narrow areas of fine granulation which are bounded by faint lines; these grooves are quite distinct for a short distance from the peristome, thus constituting a well-defined peristomial star, they then become gradually less distinct, so that as the margin is approached they can hardly be discerned.

The periproct is small, about half the diameter of the peristome, transversely suboval, about one-fourth the way from the margin to the peristome.

Related forms.—*L. archerensis* is most closely related to *L. dalli,* but can be easily distinguished by the concave ring on its upper surface, by its narrower petals, its less depressed and narrower poriferous zones, and by having its periproct closer to the margin. It is also allied to *L. floridanum,* but has a less regularly oval marginal outline and a larger petaloidal area. It differs from *L. crustuloides* in being lower centrally, in having a concave ring on its upper surface, and in having a flat lower surface.

Locality.—Archer, Fla.

Geologic horizon.—Vicksburg group, lower Oligocene.

Collection.—U. S. National Museum (164667a).

Laganum johnsoni Twitchell, n. sp.

Plate LXXV, figures 2a–d.

Description and determinative characters.—The test of this new Laganum is moderate in size and almost regularly oval in marginal outline. The upper surface is moderately elevated centrally, the height being about one-third of the width, the tumid area extending to the ends of the petals; the submarginal area about equal in thickness to the margin, which is slightly undulating, very thick, high and rounded, thicker and higher than in related forms, slightly thinner at the middle of the posterior end than elsewhere. The lower surface is decidedly concave, the concavity reaching nearly to the margin and near the peristome being about equal to one-half the height of the test. The apex is subcentral. The posterior petals are

lanceolate, the anterior three subelliptical, all of them pointed and closed at the ends, extending two-thirds or more of the way to the margin, the anterior pair slightly shorter than the rest. The poriferous zones are very narrow, much narrower than the slightly tumid interporiferous areas, sometimes irregular, inner ends poorly defined, inner row of pores round, outer row slitlike, pairs of pores conjugated. The whole surface of the test is covered with rather conspicuous small tubercles which are larger on the lower surface. The apical system is subcentral, with four large genital pores. The peristome is small, subpentagonal, subcentral; ambulacral grooves poorly defined, not well preserved on the specimen. The periproct is small, subcircular to subpentagonal, about one-third the way from the margin to the peristome.

Dimensions.—Length 34 millimeters; width 30 millimeters; height 10 millimeters.

Related forms.—This species is very closely related to *L. crustuloides*, in fact so close that further collecting may lead to its being made a synonym of the latter species. Its chief distinguishing features are its greater height and the greater height and thickness of its margin. These features distinguish it not only from *L. crustuloides*, but also from the other American representatives of the genus, from which it differs also in its pronouncedly concave lower surface.

Locality.—Turks Cave, Ala.

Geologic horizon.—Probably Vicksburg formation, lower Oligocene.

Collection.—U. S. National Museum (137202); collected by L. C. Johnson, after whom it is named.

Laganum floridanum Twitchell, n. sp.

Plate LXXV, figures 3a–d.

Determinative characters.—Test small, oval in marginal outline. General form subdiscoidal, the upper surface very low, almost parallel with the lower surface, with a slightly concave ring between the slightly tumid petaloidal area and the notably thickened margin. Apex and apical system slightly excentric anteriorly. Lower surface flat. Ambulacral petals subelliptical, very short, extending halfway to the margin, pointed and closed at ends. Petaloidal area notably smaller than in related forms. Periproct small, circular, about one-third the way from margin to peristome.

Dimensions.—Length 20 millimeters; width 18 millimeters; height 3 millimeters.

Description.—This new Laganum from Florida has a small test which is almost regularly oval in marginal outline. The whole form is greatly depressed; subdiscoidal; the upper surface being almost parallel with the lower; the apical region slightly tumid, the tumidity involving the larger part of the petals; the region around the ends of the petals concave; the margin notably thickened, slightly more so anteriorly than posteriorly. The lower surface is flat, or nearly so. The apex is slightly excentric anteriorly, at the summit of the central tumid area, which rises but very slightly above the height of the margin.

The ambulacral petals are subelliptical, somewhat pointed and closed at the ends; very short, extending only about halfway to the margin, subequal in length. The poriferous zones are very narrow, much narrower than the interporiferous areas, the proximal ends poorly defined, inner row of pores round, outer row slitlike, pairs of pores conjugated. The whole surface of the test is covered with small tubercles set in deep scrobicules, which are somewhat larger on the lower surface.

The apical system is slightly excentric anteriorly, coincident with the apex. There are four large genital pores, the anterior pair being set closer together than the posterior pair. The poriferous zones can not be seen to come together at their proximal ends, and the perforations of the radial plates can not be made out.

The peristome is small, slightly excentric anteriorly, subpentagonal. The ambulacral grooves are inconspicuous and could not be made out on the single specimen studied.

The periproct is small, about half the diameter of the peristome, circular, located about one-third the way from the margin to the peristome.

Related forms.—*L. floridanum* is closely related to *L. archerensis* and to *L. crustuloides*, but differs from both in being more regularly oval in marginal outline and in having a smaller

petaloidal area. It differs further from *L. crustuloides* in having a flat under surface, a less elevated central area, and a concave ring on the upper surface.

Locality.—Johnsons Sink, Fla.

Geologic horizon.—Vicksburg group, lower Oligocene.

Collection.—U. S. National Museum (137884).

Laganum dalli Twitchell, n. sp.

Plate LXXV, figures 4a–d.

Determinative characters.—Test small, subpentagonal in marginal outline. General form subdiscoidal, the upper surface very low, almost parallel with the flat lower surface. Apex and apical system slightly excentric anteriorly. Ambulacral petals broad, subovate, extending two-thirds the way to the margin; poriferous zones wide, depressed below the general surface, thus making the narrow interporiferous areas stand out in relief; madreporite tumid. Peristome probably subcentral. Periproct small, circular, about midway between margin and peristome.

Dimensions.—Length 16 millimeters; width 15 millimeters; height 4.5 millimeters.

Description.—The type of this handsome little Laganum was found at Archer, Fla., by W. H. Dall of the United States National Museum, in whose honor the species is named. This species occurs in association with *Laganum archerensis.* The test is small in size and subpentagonal in marginal outline. The whole form is greatly depressed, subdiscoidal, the upper surface being almost parallel with the lower. The margin is notably thickened, slightly less so at the middle of the posterior end. The lower surface is flat or nearly so. The apex is subcentral or very slightly excentric anteriorly, though it is but slightly higher than the margin of the test. There is no distinct concave ring on the upper surface, but the poriferous zones of the ambulacral petals are slightly depressed below the general surface.

The ambulacral petals are subovate in outline, broad, extending nearly two-thirds the way to the margin, rounded, blunt, and closed at the ends. The poriferous zones are very wide, as wide as the interporiferous areas, slightly depressed below the general surface; inner row of pores round, outer row slitlike, pairs of pores conjugated by very narrow grooves. Interporiferous areas narrow, standing in relief by reason of the depression of the poriferous zones. The whole surface of the test, including the interporiferous areas, is covered with small tubercles, set in deep scrobicules, which are larger on the under surface.

The apical system is subcentral or slightly excentric anteriorly, coincident with the apex. There are four large genital pores of which the anterior pair are nearer together than the posterior pair. The madreporite is tumid. No other details can be made out.

The under surface is damaged on the single specimen known and the details in regard to the peristome and ambulacral grooves can not be given, though it is evident that the peristome was central or subcentral in position.

The periproct is small, circular, about midway between the margin and the peristome.

Related forms.—*L. dalli* is most closely related to *L. archerensis*, differing chiefly in having no concave ring on the upper surface and in having its periproct farther from its margin.

L. dalli closely resembles *Sismondia antillarum* Cotteau from the Eocene of the island of St. Barthelemy but is distinguished by being thicker as a whole, especially on the borders.

Locality.—Archer, Fla.

Geologic horizon.—Vicksburg group, lower Oligocene.

Collection.—U. S. National Museum (164667b).

Order ATELOSTOMATA.

Suborder ASTERNATA.

Family NUCLEOLITIDÆ.

Genus AMBLYPYGUS Agassiz.

AMBLYPYGUS MERRILLI Twitchell, n. sp.

Plate LXXVI, figures 1a–d; Plate LXXVII, figures 1a–b, 2a–b; Plate LXXVIII, figures 1a–b.

Determinative characters.—Test large to very large, subhemispherical to depressed subconical; circular or subcircular in marginal outline; sides rounded; under surface concave. Apex central or subcentral. Ambulacral areas tumid, broad, widest between apex and ambitus; petals wide open, nearly reaching the ambitus, poriferous zones wide, slightly depressed. Peristome large, irregularly subtriangular, oblique, slightly excentric anteriorly. Periproct very large, larger than the peristome, subelliptical to subpyriform, longest longitudinally, about midway between peristome and posterior margin.

Dimensions.—Specimen A (type): Length 115.5 millimeters; width 114 millimeters; height 62 millimeters. Specimen B: Length 73 millimeters; width 69 millimeters; height 40 millimeters.

Description.—This superb Amblypygus, which is one of the largest of American echinoids, is the first representative of this rather rare genus to be reported from the United States. The type specimen was collected by G. P. Merrill, of the United States National Museum, and the species is therefore named in his honor. The test of the present species is large to very large, ranging from about 70 millimeters to about 115 millimeters in diameter. It is subhemispherical to depressed subconical in form, the upper surface declining immediately and equally on all sides from the central or subcentral apex; circular or subcircular in marginal outline. The margin is rounded and inflated; the under surface concave centrally.

The ambulacral areas are broad, widest about midway between apex and ambitus, thence narrowing to the apex and peristome; they are slightly tumid, thus forming five tumid ridges from apex to peristome. The dorsal portions of the areas are subpetaloid, the petals being long, about reaching the ambitus, wide open at their extremities. The poriferous zones are wide, slightly depressed; both outer and inner rows of pores round, pairs of pores conjugated by long, narrow grooves.

The interambulacral areas are broad. The surface of the whole test, including the interporiferous areas, is covered with numerous small perforate tubercles, with sunken scrobicules.

The apical system is large, central or subcentral. Most of the area of the system is occupied by the large, slightly tumid, granulated madreporite, which appears to be the enlarged right anterior basal plate. There are four large genital pores, the two anterior being nearer together than the posterior pair. The radial plates and their perforations can not be discerned on the specimen.

The peristome is very large, irregularly subpyriform, slightly excentric anteriorly. It is placed in an oblique position, its longest diameter being about 30° to the transverse axis of the test.

The periproct is very large, larger than the peristome, subelliptical to subpyriform, situated about halfway between the peristome and posterior margin, though slightly nearer the peristome; its longer diameter extending longitudinally.

Related forms. *Amblypygus merrilli* is not closely related to any other echinoid from the United States. Of foreign forms it resembles both *A. americanus* Michelin from the Tertiary of Jamaica[1] and *A. altus* Duncan and Sladen from the Tertiary of India, being intermediate between them in relative height. The proportion of the mean diameter to the height in *A. merrilli* is 1:55, whereas in the Jamaican form, according to Duncan and Sladen, it is 1:409 and in the

[1] Formerly good description of [illegible] Michelin, erroneously [illegible] Sladen in The Tertiary Echinoidea of Kachh and Kattiawar, p. 1, [illegible] to Desor' genus, [illegible] Museum. Sadly, the writer has [illegible] the form has never been figured.

Indian 1:0.62 or 1:0.63. *A. merrilli* also differs from *A. altus* in having its peristome more angular and less oblique and its periproct more pointed posteriorly and farther from the posterior margin. It is nearer *A. americanus* but is less depressed and has a more subconical upper surface.

Localities.—Kendrick lime quarries near Ocala, Marion County (type), and Clarke, Alachua County, Fla.

Geologic horizon.—Ocala limestone of Vicksburg group, lower Oligocene.

Collection.—U. S. National Museum (164934, A; 137870, B).

Genus OLIGOPYGUS De Loriol (amended).

Oligopygus was founded in 1887 by De Loriol on the species *Oligopygus wetherbyi* from the Tertiary of Florida and so far as known has few representatives outside of the United States. De Loriol possessed but a few specimens and, although his diagnosis is well drawn, the large number of specimens studied by the writer (over sixty) has shown the necessity of amending the description of the genus in a number of important particulars, of which the most important is noting the fact that it includes forms in which the periproct is inframarginal.

Test moderately large, with thick walls, especially at the ends; usually oval, may be subcircular, or subpentagonal; sides tumid; under surface slightly concave, with a deep, transverse depression around the peristome; upper surface convex, more or less depressed; apex central or anteriorly excentric.

Apical system central or subcentral, compact, small, with four perforated basal plates; the five radial plates small, with minute pores; madreporite central, tumid, extending to or between the posterior radial plates.

Ambulacral areas broadest at the ambitus, the anterior paired areas curving posteriorly near the peristome; faintly tumid on the upper surface; dorsal portions varying from subpetaloid to petaloid, the petals differing slightly in length and more or less open, otherwise similar. Poriferous zones broad; pores equal or nearly so, pairs united by a long groove. Beyond the petaloid portions to and beyond the ambitus each plate is perforated at its outer end by two or three pairs of very small pores.

Peristome central, or subcentral, pentagonal, slightly elongate transversely, at the bottom of the transverse depression in the under surface; floscelle and jaws wanting. Periproct very small, circular, opening on the inferior face between the peristome and the posterior margin; may be inframarginal. Tubercles small, equal, more or less scattered, surrounded by deep scrobicules and imperforate.

Oligopygus wetherbyi De Loriol.

Plate LXXVIII, figures 2a–d, 3a–b.

Oligopygus wetherbyi De Loriol, 1887, Recueil zool. Suisse, vol. 4, No. 3, pp. 396–398, Pl. XVII, figs. 7–8.
Oligopygus wetherbyi Stefanini, 1911, Soc. geol. italiana Boll,, vol. 30, p. 705.
Oligopygus wetherbyi Stefanini, 1911, Revista italiana di paleontologia, vol. 17, pt. 2, p. 11.

Determinative characters.—Test with thick walls, oval, sides tumid, upper surface depressed and rather flat on top; under surface with a very deep, long, flaring, transverse depression around the peristome. Ambulacral areas wide at the ambitus; dorsal portions petaloid, constrictions at the ends of the petals somewhat pronounced. Apex and apical system central or subcentral. Peristome pentagonal, opening at the bottom of the depression in the under surface. Periproct very small, circular, situated about midway between the peristome and posterior margin.

Dimensions.—Specimen A: Length 34 millimeters; width 29 millimeters; height 16 millimeters.

Description.—The writer has not had the opportunity of seeing the type of this species, but De Loriol's full and clear description and excellent drawings have permitted its ready identification among the material studied. The test is unusually thick, especially at the ends;

quite regularly oval in marginal outline, though sometimes narrowing anteriorly; margin rounded and inflated, the anterior end somewhat more so than the posterior, giving that end a bulging appearance forward. The upper surface is uniformly convex; but depressed and rather flat on top; under surface slightly concave near the middle and with a very deep, transverse depression around the peristome. The apex is subcentral, or slightly forward of the center.

The ambulacral areas are wide at the ambitus from which they narrow to the peristome and apex, but with somewhat pronounced constrictions at the ends of the petaloid portions; the anterior paired ambulacra curving posteriorly on approaching the peristomial depression; dorsal portions petaloid, the odd petal being longer than the others, which are equal or nearly equal in length. The poriferous zones are broad, more than half the width of the interporiferous area, moderately apart at their extremities; the pores equal or nearly so, small, elliptical; pairs of pores united by long, narrow, oblique grooves. Beyond the petaloid portions the small narrow plates of those portions give place to broad plates, each of which to and beyond the ambitus has two or three pairs of very small round pores placed obliquely near together at the extreme outer ends of the plates. The interporiferous areas are slightly tumid and stand out in relief.

The apical system is central or subcentral. The madreporite is large and tumid, central, pentagonal, the posterior edge being straight and coinciding with those of the posterior radial plates. There are four genital pores situated at the edge of the madreporite, the posterior pair being farther apart than the anterior; and there are five small subtriangular radial plates, each perforated by a very small pore.

The peristome is pentagonal, slightly elongated transversely, opening at the bottom of a very deep, long, flaring transverse depression in the middle of the under surface. The size and shape of this depression varies, but its length at the surface is usually about one-half the width, and its depth about one-half the height of the test. Its anterior and posterior walls slope at nearly the same angle but in opposite directions toward the peristome forming a broad, deep, V-shaped concavity.

The periproct is very small and circular, and situated at about midway between the peristome and the posterior margin.

Numerous small, uniform, imperforate tubercules, surrounded by deep scrobicules, are scattered irregularly over the entire surface of the test.

Related forms.—*Oligopygus wetherbyi* is most closely related to *O. floridanus* from which it can be distinguished by its more depressed form, more petaloid ambulacra, broader poriferous zones, and its deeper, longer and more open peristomial depression. It also resembles *O. haldermani*, but is readily separated by the more anterior position of its periproct.

From most foreign forms *O. wetherbyi* can be readily separated by its more profound depression around the peristome. *O. costulatus* (Desor), its nearest ally, according to De Loriol, has more markedly ridged ambulacra, a more swollen and slightly conical test, and periproct nearer the peristome. *O. ovum-serpentis* (Guppy), from supposedly Eocene deposits of Trinidad, is similar but, as noted by Stefanini, differs in having a less profound peristomial cavity and a more tumid test.

Localities.—Near Gainesville, Alachua County (De Loriol); 6 miles southwest of Gainesville, Santa Fe River, Alachua County; and Johnsons Lime Sink, Levy County, Fla.

Geologic horizon.—Vicksburg group, lower Oligocene.

Collection.—U. S. National Museum (137881a, A; 137881b, B).

Oligopygus haldermani (Conrad).

Plate LXXVIII, figures 4a–d, 5a–d.

Discoidea haldermani Conrad, 1850, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 2, p. 40, Pl. I, fig. 12.
Discoidea haldermani Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 75.
Discoidea haldermani Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 22.
Discoidea haldermani Agassiz, 1883, Mus. Comp. Zoology Mem., vol. 10, No. 1, p. 88.

Determinative characters.—Test with thick walls, marginal outline oval to subpentagonal and slightly undulating; sides tumid; upper surface usually elevated anteriorly and depressed

posteriorly, sometimes depressed subconical; under surface with a deep and more or less long and flaring transverse depression around the peristome. Ambulacral areas wide at the ambitus, dorsal portions petaloid, with a slight constriction at the ends of the petals. Apex forward of the center. Apical system central or subcentral. Peristome pentagonal, opening at the bottom of the depression in the under surface. Periproct very small, circular, inframarginal.

Dimensions.—Specimen A: Length 38 millimeters; width 33 millimeters; height 17 millimeters. Specimen B: Length 38.5 millimeters; width 31 millimeters; height 17 millimeters.

Description.—It is thought highly probable that we have here the same species which Conrad described in 1850 under the name of *Discoidea haldermani*, as some of the specimens studied came from near the same place that Conrad's form did and correspond fairly well with his figures and description. The type can not be located; and as Conrad did not figure the under surface of his form there is some doubt regarding the position of the periproct and the presence of a pronounced peristomial depression. The fact that Conrad assigned his species to the genus Discoidea, points to an inframarginal position for the periproct. Should Conrad's type ever be found, and prove to be different from the present species, then it will be necessary to give a new name to this Oligopygus.

This species appears to be the most abundant and also the most variable of the genus. The writer has had the opportunity of studying over 35 specimens, including both young and adult forms, varying in size from three-eighths inch to 1½ inches in length. The test is unusually thick. The marginal outline varies from regularly oval to subpentagonal, the former being more usual in the smaller and younger, and the latter in the larger and older forms, and is slightly undulating, which is chiefly due to broad and shallow creases in the middle of the interambulacral areas. The margin is rounded and inflated, the anterior end usually more so than the posterior, giving that end a bulging appearance in a forward direction, though at times the two ends are nearly equally inflated. The upper surface is somewhat convex, but more or less depressed and flat on top, sometimes more elevated anteriorly than posteriorly, sometimes depressed subconical in form; under surface tumid, but more or less flattened, and with a deep transverse depression around the peristome. The apex is subcentral or excentric anteriorly.

The ambulacral areas are wide at the ambitus, from which they gradually narrow to the peristome and apex, with a slight constriction at the ends of the petaloid portions; the anterior paired ambulacra curving posteriorly on approaching the peristomial depression; dorsal portions varying from subpetaloid to slightly petaloid, the odd petal being slightly longer than the others, which are equal or nearly equal in length. Poriferous zones rather broad, gradually diverging toward their extremities, then converging slightly but still wide apart at the ends; outer edges slightly depressed, forming ten more or less well defined linear grooves on the upper surface of the test; the pores equal or nearly so, small, elliptical, and conjugate. There are also several pairs of very small pores near the outer end of each plate from the ends of the petals to beyond the ambitus. The interporiferous areas are slightly tumid.

The apical system is central, or slightly excentric anteriorly. The madreporite is large, tumid and subcircular, and extends to and between the posterior radial plates. There are four genital pores, situated at the edge of the madreporite, the posterior pair being farther apart than the anterior; and there are five small radial plates, each perforated by a minute pore.

The peristome is pentagonal and opens at the bottom of a rather deep transverse depression in the middle of the under surface. This depression varies in length from one-third to one-half the width of the test, and in depth from one-fourth to one-third the height of the test; and is more or less open and flaring in form.

The periproct is very small, uniform, circular, and inframarginal.

Numerous small, uniform, imperforate tubercles, surrounded by deep scrobicules, are scattered irregularly over the entire surface of the test.

Related forms.—*Oligopygus haldermani* resembles *O. wetherbyi* and *O. floridanus* but is readily separated from both by the inframarginal position of its periproct. Of foreign forms, *O. ovum-serpentis* (Guppy), from supposedly Eocene deposits of Trinidad, is closely allied but has its periproct farther from the margin.

Localities.—Richards Quarry, Ocala, Marion County, and Johnsons Lime Sink, Levy County, Fla.; Flint River near Bainbridge, Baker County, Ga. Conrad's specimen came from a well near Bainbridge, Ga.

Geologic horizon.—Vicksburg group, lower Oligocene. The specimens from Ocala are from the Ocala limestone.

Collections.—U. S. National Museum (112506, A; 164661, B); Wagner Free Institute of Science.

Oligopygus floridanus Twitchell, n. sp.

Plate LXXIX, figures 1a–f.

Determinative characters.—Test with thick walls, oval, narrowing anteriorly; sides tumid; upper surface convex, elevated anteriorly, slightly depressed posteriorly; under surface with a deep, relatively short and narrow transverse depression around the peristome. Ambulacral areas wide at the ambitus, from which they gradually narrow to the peristome and apex; dorsal portions subpetaloid; petals wide open. Apex excentric anteriorly; apical system central or slightly excentric anteriorly. Peristome pentagonal, opening at the bottom of the depression in the under surface. Periproct very small, circular, situated about midway between the peristome and posterior margin.

Dimensions.—Length 37 millimeters; width 31 millimeters; height 19 millimeters. The dimensions of another specimen were, length 48 millimeters; width 42 millimeters; height 26 millimeters.

Description.—This new species of Oligopygus is rather rare, only three specimens being known to the writer. De Loriol may have possessed a specimen, for some of the characters he ascribes to *O. wetherbyi* apply more correctly to this species. The test is usually thick, especially at the ends; oval on marginal outline, though somewhat narrower toward the anterior end; margin rounded and inflated, the anterior end more so than the posterior, giving that end a bulging appearance in a forward direction. The upper surface is convex, somewhat elevated forward of the center, declining gradually toward the posterior end and sloping somewhat steeply on the sides; under surface tumid but slightly concave transversely near the middle, with a deep transverse depression around the peristome. The apex is forward of the center.

The ambulacral areas are wide at the ambitus, from which they gradually narrow to the peristome and apex, there being hardly any constriction at the ends of the petaloid portions, the anterior paired ambulacra curving posteriorly on approaching the peristomial depression; dorsal portions subpetaloid, the odd petal being somewhat longer than the posterior pair, which are somewhat longer than the anterior pair. The poriferous zones are narrow, nearly straight, and gradually diverge from their origin at the apex to their extremities, which are wide apart; pores small, oval, equal and conjugate. There are also several pairs of very small pores near the outer end of each plate from the ends of the petals to beyond the ambitus The interporiferous areas are slightly tumid, standing out in relief in the unweathered specimen, so as to form five straight radial ridges from apex to ambitus.

The apical system is central or somewhat excentric anteriorly. The madreporite is large and tumid, central, shield shaped; the posterior end being pointed and extending between the posterior radial plates. There are four genital pores, situated at the edge of the madreporite, the posterior pair being farther apart than the anterior; and there are five small radial plates, each perforated by a very small pore.

The peristome is pentagonal and opens at the bottom of a deep, transverse depression in the middle of the under surface. This depression is relatively short and narrow; its length at the surface being about one-third the width and its depth about one-third the height of the test. Its anterior wall is nearly vertical or even inclined slightly toward the anterior end but at a much steeper angle than the posterior wall, thus forming a deep, narrow, anteriorly projecting concavity.

The periproct is very small and circular; and situated about midway between the peristome and the posterior margin.

Numerous small, uniform, imperforate tubercles, surrounded by deep scrobicules, are scattered irregularly over the entire surface of the test.

Related forms.—*Oligopygus floridanus* is closely related to *O. wetherbyi*, from which it can be separated by its higher and less flattened upper surface, its subpetaloid ambulacra, narrower poriferous zones, and its shorter, less flaring, anteriorly projecting peristomial depression. It also resembles *Oligopygus haldermani* but can at once be distinguished by the more anterior position of its periproct.

Of foreign forms, *O. ovum-serpentis* (Guppy), from supposedly Eocene deposits of Trinidad, is closely allied; but its periproct is nearer the margin and its peristomial depression less pronounced.

Locality.—Nigger Sink, 2 miles south of Gainesville, Alachua County, Fla.

Geologic horizon.—Vicksburg group, lower Oligocene.

Collection.—U. S. National Museum (164660).

Family CASSIDULIDÆ.

Genus CASSIDULUS Lamarck.

Cassidulus (Pygorhynchus) georgiensis Twitchell, n. sp.

Plate LXXIX, figures 2a–d.

Determinative characters.—Test broadly oval, upper surface convex, moderately elevated, sides and anterior end rounded; posterior end obliquely truncated, under surface flat, curving upward slightly posteriorly to meet the posterior truncation in an angular margin; apex subcentral. Ambulacral areas narrow; petals narrow, nearly closing, the posterior pair having the inner poriferous zone of each petal shorter than the outer zone. Apical system excentric anteriorly. Peristome excentric anteriorly, pentagonal, transversely elongate, with a floscelle. Periproct small, subrhomboidal, transverse; located at the top of the rather high posterior truncation, beneath a rounded, somewhat protruding expansion of the test.

Dimensions.—Length 26 millimeters; width 22.5 millimeters; height 15 millimeters. Another specimen, of nearer average size gave, length 35 millimeters; width 32 millimeters; height 20 millimeters.

Description.—This new Cassidulus, which is rather rare, only three specimens being reported, has a test which is broadly oval in marginal outline, more obtusely rounded posteriorly than anteriorly, and obliquely truncated at the posterior end. The upper surface is regularly convex, moderately elevated, in the form of a low, rounded ridge above the periproct, sides and anterior end rounded and inflated; under surface flat, curving upward slightly posteriorly to meet the oblique posterior truncation in an angular margin, the angle formed being about 75°. The apex is subcentral.

The ambulacral areas are narrow, dorsal portions petaloid, the petals narrow, partly open at the ends, the posterior petals longer than the others, which are nearly equal in length. The poriferous zones are narrow; the inner zone of each of the posterior pair of petals shorter than the outer zone; outer row of pores slitlike, inner row round; pairs of pores conjugate.

The surface of the test is closely set with numerous small tubercles which increase in size on the under surface except along a rather wide median band which is free from tubercles and dotted with numerous small pits. The tubercles are set in scrobicules which are shallow and irregularly shaped on the upper surface; but become larger, deeper and more regular in form on the under surface.

The apical system is excentric anteriorly. The only details which can be made out are the existence of four genital pores, of which the anterior pair are nearer together than the posterior, and five small perforated radial plates.

The peristome is excentric anteriorly, immediately beneath the apical system, pentagonal, transversely elongate, with a floscelle of which the phyllodes are rather well defined and the bourelets are large and prominent.

The periproct is relatively small, about 3 or 4 millimeters in length, subelliptical to subrhomboidal, transverse; and located relatively high up on the posterior surface, at the top of the rather high posterior truncation, beneath a rounded, transverse, somewhat protruding expansion of the test.

Related forms.—*Cassidulus georgiensis* is readily separated from the other representatives of the genus from American deposits. In some features it resembles *Cassidulus carolinensis*, but it can be distinguished by its flatter under surface, more obtusely rounded and more angular posterior margin, higher and more oblique posterior truncation, and smaller periproct. Of foreign forms *C. georgiensis* resembles some forms of *Pygorhynchus grignonensis* (Defrance) Agassiz from the Eocene of France, but can be separated by its more oblique posterior truncation, more angular posterior margin, and higher placed periproct.

Localities.—Flint River, near Bainbridge, Baker County, and 2½ miles north of Cuthbert, Ga.; Alabama (exact location unknown).

Geologic horizon.—Vicksburg formation, lower Oligocene. Possibly also Jackson formation, upper Eocene. The matrix is a yellow mass of foraminiferal remains.

Collections.—U. S. National Museum (164347); Yale University.

Cassidulus (Pygorhynchus) gouldii (Bouvé).

Plate LXXIX, figures 3a–d; Plate LXXX, figures 1a–f, 2a–d.

Pygorhynchus gouldii Bouvé, 1846, Boston Soc. Nat. History Proc., vol. 2, p. 192.
Pygorhynchus gouldii Bouvé, 1847, Am. Jour. Sci, 2d ser., vol. 3, p. 437.
Pygorhynchus gouldii Bouvé, 1847, Annals and Mag. Nat. History, 1st ser., vol. 20, p. 142.
Nucleolites mortoni Conrad, 1850, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 2, p. 40, Pl. I, fig. 11.
Pygorhynchus gouldii Bouvé, 1851, Boston Soc. Nat. History Proc., vol. 4, pp. 2-4, two figures in text.
Pygorhynchus gouldii Desor, 1858, Synopsis des échinides fossiles, p. 299.
Ravenelia gouldii McCrady, 1859, Elliott Soc. Nat. History Charleston Proc., vol. 1, pp. 282, 283, no figure.
Pygorhynchus gouldii Dujardin and Hupé, 1862, Histoire nat. zoophytes échinodermes, p. 585.
Pygorhynchus gouldii Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 74.
Pygorhynchus gouldii Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 22.
Pygorhynchus gouldii Agassiz, 1883, Mus. Comp. Zoology Mem., vol. 10, No. 1, p. 91.
Pygorhynchus gouldii Cotteau, 1888, Paléontologie française, Échinides éocènes, vol. 1, p. 550.
Pygrohynchus gouldii Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, No. 87, p. 77.
Nucleolites mortoni Boyle, 1893, U. S. Geol. Survey Bull. 102, p. 200.
Pygorhynchus gouldii Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 696.

Determinative characters.—Test irregularly subconical, broadly ovate, broadest back of middle; variable in height; margin flat along the sides, angular at the ends, sharply angular under periproct; upper surface elevated anteriorly, more or less obliquely flattened and depressed posteriorly, under surface slightly concave longitudinally. Apex excentric anteriorly. Ambulacral areas broad in petaloidal region, narrow beyond; petals long, rather sharply pointed at both ends, almost closing. Apical system excentric anteriorly or subcentral. Peristome transversely elongate, excentric anteriorly, more so than the apical system, with floscelle. Periproct elliptical, transverse, supramarginal, at the top of a shallow groove, and beneath an overhanging expansion of the test.

Dimensions.—Specimen A (type): Length 52 millimeters; width 49 millimeters; height 25 millimeters. Specimen B: Length 35 millimeters; width 33 millimeters; height 18 millimeters. Specimen C (unusually high): Length 38 millimeters; width 36 millimeters; height 24 millimeters.

Description.—The species was reported and an excellent description given as early as 1846 by T. T. Bouvé of Boston, whose type specimen the writer has had the privilege of studying. The form, which though one of the best known in the literature was formerly considered rather rare, has been shown by recent collections made by the members of the United States Geological Survey and others to be one of the most abundant of American Cenozoic echinoids. It is especially abundant in Florida, where it has been found at many localities. The species is very variable, its extreme specimens differing so much in a number of details that they might be

regarded as different species were it not for the intermediate forms found in the large amount of available material. Many of the specimens are only well-preserved casts.

The test is irregularly subconical in form; the marginal outline broadly ovate, broadest back of the middle; margin thick and vertically flattened along the anteriorly converging side portions, more or less angular at the ends, sharply angular beneath the periproct. The upper surface varies from rather low and depressed to moderately high. It is irregularly subconical; the apex being more or less excentric anteriorly, the side and anterior surfaces sloping nearly equally and somewhat steeply though with a more or less rounded contour, and the posterior surface sloping less steeply and being more or less flattened, except for a slight tumidity above the periproct. The under surface is concave along the longitudinal median area. The apex is excentric anteriorly, sometimes coincident with, sometimes anterior to the apical system.

The ambulacral areas are narrow at the ambitus, dorsal portions petaloid; petals rather wide, long, the posterior pair slightly longer than the anterior pair which are slightly longer than the odd petal, rather sharply pointed at both ends, almost closing at their extremities. The poriferous zones are rather wide, slightly depressed; pores subequal, outer row oval, inner row round; pairs of pores conjugate; interporiferous areas slightly tumid.

The surface of the test is closely set with small scrobiculate tubercles which increase in size on the under surface except along a rather narrow pitted median area.

The apical system is excentric anteriorly in most specimens, but is subcentral in some. In most it is coincident with the apex but in some it is slightly back of it. Because of the poor character of the specimens, the details can rarely be made out. There are four perforated basal plates, the anterior genital pores being nearer together than the posterior, and five small perforated radial plates.

The peristome is pentagonal, somewhat elongate transversely, excentric anteriorly, more so than the apical system, being about three-eighths the length of the test from the anterior margin; and apparently more fixed in its relative position than the apical system. It is surrounded by a well-defined floscelle with rather prominent bourrelets. On the casts the phyllodes form prominent radial ridges around the peristome.

The periproct is moderately large, elliptical, transverse, supramarginal, rather low and near the posterior end, beneath a low, rounded, transverse expansion of the test. Beneath the periproct there is a depression which renders the margin at this point thinner or more sharply angular than it is elsewhere.

Related forms.—Among American forms *Cassidulus gouldii* is most nearly related to *C. alabamensis* but can readily be distinguished by its smaller size, less subquadrate form, and more steeply sloping sides. It does not appear to very closely resemble any foreign forms.

Localities.—Baker County (type); Laurenden Creek; Hawkinsville; A. E. Belcher's well, Decatur County; 32 miles south of Macon, on Georgia & Florida Railroad; Ellaville; 2½ miles north of Cuthbert, Ga. Two miles south of Gainesville; 6 miles southwest of Lake City; Santa Fe River, Alachua County, Pembertons Ferry, Withlacoochee River 4 and 5 miles west of Live Oak; deep wells at Padlock, 7 miles south of Live Oak; Sulphur Springs Ferry, Suwannee County, Fla.

Geologic horizon.—Vicksburg group, lower Oligocene, possibly Eocene also. Bouvé said his form was from the "Millstone grit" and Conrad said his was from the "Buhrstone"; consequently the species has hitherto been regarded as Eocene; but nearly all of the large number of specimens studied by the writer came from Oligocene deposits.

Collections.—Boston Society of Natural History (1756, A); U. S. National Museum (137904, B; 137904a, C); Academy of Natural Sciences of Philadelphia; Wagner Free Institute of Science.

Cassidulus (Pygorhynchus) alabamensis Twitchell, n. sp.

Plate LXXX, figures 3a–d.

Determinative characters.—Test large, subquadrate, depressed; upper surface convex, declining from apex nearly equally on all sides; under surface concave longitudinally. Apex subcentral, slightly to the rear of the anteriorly eccentric apical system. Ambulacral areas

broad in petaloidal portion, narrow beyond; petals long, subequal in length, almost closing. Peristome rather large, pentagonal, transversely elongate, excentric anteriorly, more so than the apical system, with a floscelle. Periproct rather large, elliptical, transverse, supramarginal, at the top of a broad shallow groove and beneath an overhanging expansion of the test.

Dimensions.—Length 69 millimeters; width 63 millimeters; height 29 millimeters.

Description.—This large Cassidulus, the largest representative of the genus from American Cenozoic deposits, is very rare, only a few specimens having been discovered. The test is moderate to large in size, moundlike in form, depressed, subquadrate in marginal outline; margin thick, somewhat flattened on the sides, more angular at the ends, sharply angular beneath the periproct. The upper surface is convex, and declines gently from the apex nearly equally on all sides, though the side outlines tend to be straight while the end outlines tend to be curving; a slight tumidity exists along the medial line above the periproct. The under surface is decidedly concave along a broad, longitudinal median area. The apex is nearly central, being but slightly excentric anteriorly.

The ambulacral areas are narrow at the ambitus, dorsal portions petaloid; petals rather wide, long, of nearly equal length, almost closing at their extremities. The poriferous zones are rather wide, slightly depressed; pores subequal, outer row oval, inner row round; pairs of pores conjugate; interporiferous areas slightly tumid.

The surface of the test is closely set with small scrobiculate tubercles which increase in size on the under surface except along a rather narrow median pitted area.

The apical system is large and slightly excentric anteriorly, somewhat anterior to the apex. There are four genital pores, the anterior pair being nearer together than the posterior, and there are five minute pores perforating the radial plates.

The peristome is rather large, pentagonal, transversely elongate, excentric anteriorly, more so than the apical system, being about three-eighths the length of the test from the anterior margin. It is surrounded by a large, well-defined floscelle, with prominent bourrelets.

The periproct is rather large, elliptical, transverse, supramarginal, rather high up, at the top of a broad shallow groove and beneath a rounded overhanging expansion of the test.

Related forms.—*Cassidulus alabamensis* is closely related to *C. gouldii*, from which it is readily separated by its greater size and its relatively low almost regularly convex upper surface. It does not appear to be closely related to any foreign form.

Localities.—Natural Bridge, St. Stephens, Ala.; A. E. Belcher's well, Decatur County, Ga.

Geologic horizon.—St. Stephens limestone (upper part), lower Oligocene.

Collection.—Johns Hopkins University (type).

Genus ECHINOLAMPAS Gray.

ECHINOLAMPAS ALDRICHI Twitchell, n. sp.

Plate LXXXI, figures 1a–d, 2.

Determinative characters.—Test large, subcircular; margin rounded; upper surface depressed subconical, sloping more steeply anteriorly than posteriorly; under surface concave, posterior end slightly rostrate; apex forward of the center. Ambulacral areas rather narrow, dorsal portions petaloid; petals long, open at the ends, poriferous zones of some petals unequal in length, interporiferous areas tumid. Apical system excentric anteriorly. Peristome large, excentric anteriorly, slightly less so than apical system, pentagonal, transversely elongate, surrounded by a floscelle with feeble phyllodes and bourrelets. Periproct large, elliptical, transverse, inframarginal.

Dimensions.—Specimen A (type, smaller than the average): Length 56 millimeters; width 54 millimeters; height 26 millimeters. Largest specimen: Length 80 millimeters; width 75 millimeters; height 37 millimeters.

Description.—Of this fine Echinolampas the only specimens so far reported belong to T. H. Aldrich, of Birmingham, Ala., in whose honor the species is named.[1] The test is large (ranging

[1] The Aldrich collection is now owned by the Johns Hopkins University.

from 2 to 3 inches in diameter) and about half as high as broad. The marginal outline is broadly oval to subcircular; sometimes, especially in the larger and older forms, slightly broader posteriorly than anteriorly and broadly V-shaped at the posterior end; margin tumid and rounded. The upper surface is depressed subconical, though at times approaching a depressed subhemispherical contour, sloping more steeply anteriorly and on the sides than posteriorly; under surface concave, though slightly tumid around the margin except along the posterior ambulacral areas where there are broad and very shallow depressions which give the posterior end of the test a slightly rostrate appearance. The apex is forward of the center, about two-fifths of the length of the test from the anterior end, coincident with the apical system.

The ambulacral areas are rather narrow, dorsal portions petaloid; petals long, rather narrow, open at their extremities, the posterior pair slightly longer than the anterior pair which are slightly longer than the odd petal; interporiferous areas tumid. The poriferous zones are rather narrow, slightly depressed, the inner zone of each of the posterior petals and the anterior zone of each of the anterior paired petals being slightly straighter and shorter than its fellow, the differences being the more pronounced in the anterior pair; outer pores slitlike, inner pores round, pairs of pores conjugate.

The whole surface of the test is closely set with very small, uniform tubercles in sunken scrobicules.

The apical system is excentric anteriorly. There are four perforated basal plates, the anterior pair of genital pores being nearer together than the posterior, and five small perforated radial plates. The madreporite is large, occupying the larger part of the system, and extending back between the posterior radial plates.

The peristome is rather large, excentric anteriorly, slightly less so than the apical system, pentagonal, transversely elongate, at the deepest portion of the concave under surface, and surrounded by a floscelle with feeble, straight phyllodes and low, broad, tumid bourrelets.

The periproct is rather large, elliptical, the posterior side slightly less convex than the anterior, transverse, inframarginal, very close to the posterior margin.

Related forms.—*Echinolampas aldrichi* is quite unlike *Echinolampas appendiculatus*, the only other representative of the genus found in the Cenozoic deposits of the United States. Of foreign forms it is very similar to *Echinolampas affinis* (Goldfuss) Agassiz, which occurs in the Eocene of Belgium and France, but it is to be distinguished by its more anteriorly excentric apex and the somewhat unequally excentric positions of its apical system and peristome. It also resembles *Echinolampas insignis* Duncan and Sladen from the Nummulitic series of the Tertiary of India, from which, however, it differs in being smaller, less elevated, and having its apex more excentric anteriorly.

Localities.—Gainestown, and Choctaw Bluff, Alabama River, Alabama; Mississippi (exact locality unknown).

Geologic horizon.—St. Stephens limestone, Alabama; Vicksburg limestone, Mississippi; lower Oligocene.

Collection.—Johns Hopkins University (T 1099, A).

Suborder STERNATA.

Family SPATANGIDÆ.

Genus AGASSIZIA Valentin.

AGASSIZIA CONRADI (Bouvé).

Plate LXXXI, figures 3a–d.

Hemiaster conradi Bouvé, 1851, Boston Soc. Nat. Hist. Proc., vol. 4, p. 3, figures in text.
Hemiaster conradi Desor, 1858, Synopsis échinodermes fossiles, p. 373.
Hemiaster conradi Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 75.
Hemiaster conradi Conrad, 1866, Check list, Eocene and Oligocene.
Ditremaster conradi Cotteau, 1887, Paléontologie française, Échinides éocènes, vol. 1, p. 427.
Agassizia floridana De Loriol, 1887, Recueil zool. Suisse, vol. 4, pp. 398–401, Pl. XVII, fig. 9.
Opissaster conradi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 700.
Agassizia floridana Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 705.

Determinative characters.—Test small, ovoid, upper surface high. Apical system very excentric posteriorly. Ambulacra narrow, anterior indistinct in shallow depression and with short petals in shallow groove. Surface covered with very small tubercles. Peripetalous fasciole indistinct. Peristome large. Periproct high on posterior truncation.

Dimensions.—Length 18 millimeters; width 16 millimeters; height 14 millimeters.

Description.—This small delicate form is different from any other Tertiary species. The test is ovoid, much elevated, the high apex giving a subconical appearance to the upper surface. The apex is very excentric posteriorly and the upper surface slopes from it in all directions. The under surface is convex except for the peristomial depression.

The ambulacra are narrow, the anterior hardly distinguishable on a nearly flush surface which shows a slight depression. The paired ambulacra have short petals in shallow grooves, the posterolateral pair being not half the length of the anterolateral.

The interambulacra are broad, the upper portions of the paired areas near the apex being gibbous and terminating in short, narrow ridges. The posterior interambulacrum has a pronounced truncation, which slopes inward so that the periproct is not visible from above but is from below.

The fascioles are very narrow and only traces of them can be seen here and there.

The peristome is large and bilabial. The periproct is quite large, transverse oval, slightly overhung by the projecting interambulacrum.

The apical system consists of four genital plates, the perforations of which are near together.

Related forms.—This species is easily distinguished from other species of this genus by its much elevated upper surface, slightly conical at the apex, and its very excentric apex posteriorly. The sharp truncation of the posterior surface is very characteristic. These and other characters distinguish it from *A. excentrica*, which still lives in the Caribbean Sea and near the coasts of Florida and also from *A. clevei* of the Miocene of the island of St. Barthelemy.

Localities.—Georgia (Bouvé); near Bainbridge (figured specimen) and 3½ miles south of Sasser on Dawson-Albany public road, Georgia; near Gainesville, Fla.

Geologic horizon.—Lower Oligocene.

Collection.—U. S. National Museum (164744); Geological Survey of Georgia.

Genus SCHIZASTER Agassiz.

SCHIZASTER FLORIDANUS Clark, n. sp.

Plate LXXXII, figures 1a–c.

Determinative characters.—Test rather large, cordiform, high posterior upper surface, nearly flat lower surface. Ambulacra in broad, deep grooves, the petals of the paired ambulacra being very pronounced. Posterior truncation prominent with high periproct. Peristome near anterior margin.

Dimensions.—Length 50 millimeters; width 24.5 millimeters; height 30 millimeters.

Description.—The species is represented only by forms in which the test has been replaced by silica, obliterating some of the features but admirably preserving others.

The test is of rather large size, cordiform, with a sloping upper surface which extends up from the depressed anterior margin to the much elevated posterior margin. The lower surface is nearly flat.

The ambulacra are broad, the anterior ambulacrum being in a broad deep groove which passes over the anterior margin. The paired ambulacra have broad deep petals, the anterolateral pair being about one and one-half times as long as the posterolateral.

The interambulacra are wide and are slightly gibbous near the apex. The posterior area has a sharp ridge reaching to the posterior margin. A pronounced truncation characterizes this area, the slope being actually inward and the periproct being found high on the surface. The peristome is large and near the anterior margin.

Locality.—Johnsons Sink, Levy County, Fla.

Geologic horizon.—Vicksburg group, lower Oligocene.

Collection.—U. S. National Museum (164655).

Schizaster americana Clark, n. sp.

Plate LXXXII, figures 2a–d.

Determinative characters.—Test medium size, subpentagonal, as wide as long, upper surface elevated posteriorly. Ambulacra narrow, the anterior deeply sunken in deep groove; the paired ambulacra with short petals, the posterior about one-half the length of the anterior. Interambulacra broad, prominent. Peristome near anterior margin, in well-marked depression. Periproct high on truncated posterior margin, peripetalous and lateral fascioles clearly marked.

Dimensions.—Length 39 millimeters; width 39 millimeters; height 25 millimeters.

Description.—The species has a test of medium size, rather tall, subpentagonal, as wide as long, sloping up from the anterior margin to the nearly central apical system, beyond which a sharp rise continues toward the posterior margin, its highest point being about midway.

The ambulacra are narrow, the anterior one situated in a deep, moderately wide groove that indents the anterior margin. The paired ambulacra have deep short petals, the anterolateral being about twice as long as the posterolateral.

The interambulacra are broad and somewhat gibbous on the sides. The posterior interambulacrum is much elevated and rather narrow. The surface is covered with numerous small but clearly distinct tubercles with small granules between them. The peripetalous and lateral fasciole can be readily traced.

The apical system is small and nearly central in position. The peristome is near the anterior margin in a well-marked depression. The periproct is high on the truncated posterior margin.

Localities.—Yost limekiln near Brandon station, Rankin County (type), and Clarke County, Miss.; 5 miles south of Ellaville, on Ellaville-Americus public road, Georgia.

Geologic horizon.—Vicksburg formation, lower Oligocene.

Collection.—U. S. National Museum (165695); Geological Survey of Georgia.

Eupatagus floridanus Clark, n. sp.

Plate LXXXII, figures 3a–d; Plate LXXXIII, figures 1a–c, 2a–d.

Determinative characters.—Test large, elongate, subcordiform, depressed, sloping from anterior margin to point half way from apical system to posterior truncation. Ambulacra nearly flush, poriferous zones somewhat sunken, paired ambulacra with long petals. Interambulacra with large perforate and crenulate tubercles irregularly scattered over surface. Fascioles distinct. Peristome small. Periproct large.

Dimensions.—Specimen A: Length 65 millimeters; width 56.5 millimeters; height 31.5 millimeters. Specimen B: Length 67 millimeters; width 56 millimeters; height 30 millimeters. Specimen C: Length 49 millimeters; width 39.5 millimeters; height 23 millimeters.

Description.—A number of specimens of this striking form have been found in the Oligocene of Florida. The test is large, elongate, subcordiform, and depressed. The upper surface slopes from the low anterior margin gradually to the high posterior apex which is situated about halfway from the apical system to the beginning of the posterior truncation. The lower surface is nearly flat.

The ambulacra are wide nearly flush and the poriferous zones somewhat sunken. The paired ambulacra have long, closed petals the posterolateral longer than the anterolateral. The pore openings of the petaloidal portions are small and round, the pore pairs connected by deep furrows.

The interambulacra consist of large plates covered somewhat irregularly with large perforate and crenulate tubercles, the greater number occurring in more or less horizontal rows along the upper part of the plates above the ambitus.

The apical system is anterior to the center of the upper surface, is small and nearly flush.

The fascioles are distinct here and there. The peristome is small and semicircular. The periproct is large, occupying much of the truncated surface.

Related forms.—This species has many points of similarity to *E. clevei* Cotteau of St. Barthelemy Island, although it differs in some minor particulars. It may prove to be the same species.

Locality.—Johnsons Sink (type specimen A), Levy County (type specimens B and C), Fla.
Geologic horizon.—Vicksburg group, lower Oligocene.
Collections.—U. S. National Museum (137881, A); Wagner Free Institute of Science (B); Museum of Comparative Zoology.

Class HOLOTHURIOIDEA.

Order PARACTINOPODA.

Family SYNAPTIDÆ.

Genus CHIRODOTA Eschscholtz.

CHIRODOTA sp.

Chirodota sp. Cunningham, 1895, Am. Micr. Jour., vol. 16, pp. 193–196, and figs. 1 and 2.

Description.—Small holothurian plates are figured by Cunningham and referred to the genus Chirodota. No material has been accessible for the present investigation.
Locality.—Near Red Bluff station, Chickasawhay River, Clarke County, Miss.
Geologic horizon.—Vicksburg limestone, lower Oligocene.
Collection.—K. M. Cunningham, Mobile, Ala.

Genus SYNAPTA Eschscholtz.

SYNAPTA sp.

Synapta sp. Cunningham, 1895, Am. Micr. Jour., vol. 16, pp. 193–196, and figs. 3–6.

Description.—Fragments of small plates and a spicule are figured by Cunningham and referred to the genus Synapta. No material has been accessible for the present investigation.
Locality.—Near Red Bluff station, Chickasawhay River, Clarke County, Miss.
Geologic horizon.—Vicksburg limestone, lower Oligocene.
Collection.—K. M. Cunningham, Mobile, Ala.

MIOCENE ECHINODERMATA.

Class STELLEROIDEA.

Subclass ASTEROIDEA.

Order CRYPTOZONIA.

Family ASTERIIDÆ.

Genus ASTERIAS Linné.

ASTERIAS REMONDII Gabb.

Asterias remondii Gabb, 1869, Geol. Survey California, Paleontology, vol. 2, pp. 37, 38, Pl. XIII, fig. 69.
Asterias remondi Cooper, 1888, State Mineralogist California Seventh Ann. Rept., p. 270.
Asterias remondi Weaver, 1909, Univ. California Dept. Geology Pub., vol. 5, No. 16, p. 261.

Description.—Since no material representing this species has been accessible for study the description of Gabb is given verbatim:

Animal large, robust, five rayed; rays more than twice as long as the diameter of the disk, thick on the margin. Upper surface covered by short, club-shaped spines, narrow toward the base, and bluntly rounded above; on the sides these same spines are more closely placed, and on the undersurface they are so close that they are in contact; ambulacræ broad, bearing numerous small, very slender spines.

Locality.—Star Fish Point, Martinez, Contra Costa County, Cal. (Cooper), San Pablo Bay, Cal. (Weaver).

Geologic horizon.—San Pablo formation, upper Miocene.

Collection.—Unknown.

Subclass OPHIUROIDEA.

Order ZYGOPHIURÆ.

Family OPHIODERMATIDÆ.

Genus OPHIODERMA Müller and Trosch.

OPHIODERMA (?) sp.

Plate LXXXIV, figure 1.

Ophioderma ? sp. Clark, 1904, Maryland Geol. Survey, Miocene, p. 433, Pl. CXX, fig. 3.

Description.—Fragments of the arms of an Ophiurian occur in the indurated ledge just above sea level along St. Marys River. It is impossible to determine the relations of the form with accuracy, but it is probably an Ophioderma. The fragments were found in the interior of the shells of large gastropods.

Locality.—St. Marys River, Md.

Geologic horizon.—St. Marys formation, middle Miocene.

Collection.—Johns Hopkins University (T 1000).

Family AMPHIURIDÆ.

Genus AMPHIURA Forbes.

AMPHIURA SANCTÆCRUCIS Arnold.

Plate LXXXIV, figures 2 and 3.

Amphiura sanctæcrucis Arnold, 1903, U. S. Nat. Mus. Proc., vol. 34, pp. 403–406, Pl. XI, figs. 1, 2.

Description.—Arnold describes the species as follows:

Disk attaining a diameter of 13 millimeters, delicate, covered with small naked overlapping scales. Arms five, long, slender, even or tapering very slightly and more or less flattened. Arm spines moderately short and sharp

pointed, approximately equal in length to the width of the dorsal median plates. Under arm plates simple, breadth about 1½ length; lower arm plates deeply grooved in the median line.

Disk pentagonal in outline, the arms passing out from the sides rather than from the angles, this being due to the spreading of the disk upon compression by the containing fine clayey sediments; whole dorsal surface of disk covered with overlapping scales, which, in the cast serving as the type, are minutely shallowly punctuate corresponding to numerous microscopic protuberances in the original animal. Radial shields moderately large, of a short, pear-seed shape, pointed within, outer edge sharply rounded, inner edges nearly straight and separated by five prominently overlapping scales (the continuation of the upper arm scales, but shorter than the latter) which narrow rapidly toward the points of the shields. Between the radial shields of adjacent arms are about seven rows of small overlapping plates, the middle row apparently much larger than the others. The specimen exhibiting the ventral side is so much crushed that its characteristics are unrecognizable. Upper arm plates simple, small, breadth about 1½ length, slightly narrowed within, broader without, straight front, back, and sides. Side plates small, triangular, with sharp cornered, beveled edges. Under arm plates quite similar to upper, except deeply medially longitudinally grooved. Spines at least four to a segment; about 1½ times length of upper arm plates, rounded, sharp.

Dimensions.—Specimen exhibiting dorsal surface: Diameter of disk 13 millimeters; arms at least 25 millimeters long and probably several times this amount; width near disk 2 millimeters, upper arm plates 0.7 to 0.8 millimeter long.

Specimen exhibiting ventral surface: Diameter of disk 6.5 millimeters; arm at least 20 millimeters long and probably at least twice this length judging by taper.

Notes.—The two specimens upon which this species is founded are beautifully preserved molds, the larger one, which is taken as the type, showing the dorsal surface, the smaller one the ventral. As would be expected, the surfaces of the disks are considerably crushed and distorted, but enough characteristics are visible to admit of the above specific description. The specimens have been compared with the recent alcoholics in the collection of the United States National Museum, but no forms agreeing even remotely with the fossils were found. Both A. H. Clarke and the writer are of the opinion that the fossils belong to the genus Amphiura, although, as might be expected in molds, some of the diagnostic characters are lacking. The species is named in honor of the Santa Cruz quadrangle, near which the types were obtained.

Locality.—Hills immediately southeast of Scott Valley, 6 miles north-northeast of Santa Cruz, Santa Cruz County, Cal.

Geologic horizon.—Santa Margarita formation, middle or upper Miocene.

Collection.—Stanford University (1078); U. S. National Museum (165431).

Class ECHINOIDEA.

Subclass REGULARIA ENDOBRANCHIATA.

Order CIDAROIDEA.

Family CIDARIDÆ.

Genus CIDARIS Leske.

Cidaris thouarsii (?) Valenciennes.

Cidaris thouarsii Valenciennes, 1846, Agassiz and Desor, Cat. raisonné des échinodermes, Soc. nat. Ann., vol. 6, p. 326.
Cidaris sp. *a* Arnold, 1908, U. S. Nat. Mus. Proc., vol. 34, pp. 351, 359.
Cidaris sp. *a* Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 701.

Description.—This species, which Arnold has referred to under the name of *Cidaris sp. a*, is regarded by H. L. Clark as probably *C. thouarsii*. He says in a letter quoted by Arnold:

> The wax cast [*Cidaris* sp., a] is a spine of a true Cidaris and very much like many spines of some individuals of the species of Cidaris common on the west coast of Lower California, Mexico, and Central America, *C. thouarsii*. I do not think it shows a single feature by which it can be distinguished from *thouarsii*, it is certainly from the ancestor of that species.

Locality.—Santa Cruz quadrangle, Cal.

Geologic horizon.—Monterey shale, middle Miocene.

Collection.—U. S. National Museum.

Subclass REGULARIA ECTOBRANCHIATA.

Order DIADEMOIDEA.

Suborder ARBACINA.

Family ARBACIIDÆ.

Genus ECHINOCIDARIS Duncan.

ECHINOCIDARIS sp. McCrady.

Echino-cidaris sp. McCrady, 1855, in Tuomey and Holmes, Pliocene fossils of South Carolina, Pl. II, figs. 5, 5a.
Arbacia sp. Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 707.

Description.—An illustration of this form "restored from several fragments" is given by McCrady but no description is furnished. Its generic relations are very questionable because of doubt as to the accuracy of the drawing.

Locality.—South Carolina.

Geologic horizon.—Miocene (?).

Collection.—Unknown.

Genus CŒLOPLEURUS Agassiz.

CŒLOPLEURUS IMPROCERUS (Conrad).

Plate LXXXIV, figures 4a–c.

Echinus improcerus Conrad, 1843, Acad. Nat. Sci. Philadelphia Proc., vol. 3, p. 310.
Psammechinus improceras Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 705.

Determinative characters.—Test large, circular, depressed, concave below. Ambulacra narrow, each with two rows of primary tubercles extending from peristome over ambitus about two-thirds of way from latter to apical system, secondary tubercles above; poriferous zones narrow, slightly flexuous. Interambulacra wide, the two rows of primary tubercles on upper surface small. Peristome large, with slight brachial incisions.

Dimensions.—Diameter 35 millimeters; height 15 millimeters.

Description.—This species was first described by Conrad in 1843. No illustration accompanies the description, but the species is without doubt the form found by the authors in the Yorktown formation near the James River and figured and described in this monograph. It corresponds in all particulars to the incomplete description which Conrad gives to it.

The test is large, circular and depressed. The slope of the upper surface is very low toward the apex. The lower surface is concave.

The ambulacra are narrow, each bearing two rows of primary tubercles which are much larger at the ambitus than on the lower or upper surface. They diminish rapidly in size on the upper surface and about two-thirds of the way to the apical system become secondaries or diminish altogether. One or more isolated primaries also occur at this point of disappearance with a secondary between. The poriferous zones are narrow and somewhat sinuous, the pore pairs uniserial.

The interambulacra are broad with four rows of primary tubercles at the amibitus similar to those of the ambulacra. They become smaller, reduced in number, and more or less irregularly crowded together near the peristome. Above the ambitus the rows of primary tubercles are soon reduced to two which with diminished size continue to the apical system. A large, miliary median space is found in the upper portion of each interambulacrum.

The apical system is large but much broken in the type specimen. The peristome is large with small branchial incisions. The periproct is large and elongate.

Localities.—James River, near Smithfield (type); J. T. Williams's marl pit, Smith Creek, half a mile below Suffolk, Va. (figured specimen).

Geologic horizon.—Yorktown formation, upper Miocene.

Collection.—U. S. National Museum (166487).

Cœlopleurus sloani Clark, n. sp.

Plate LXXXIV, figures 5a–b.

Determinative characters.—Test moderate size, circular, elevated. Ambulacra narrow, each with two rows of primary tubercles which rapidly diminish in size above the ambitus. Interambulacra with median space on upper surface without tubercles. Apical system prominent. Peristome small. Periproct large, subpentagonal.

Dimensions.—Diameter 27 millimeters; height 15 millimeters.

Description.—This species has a test of medium size, circular in ambital outline and much elevated. The apex is high and the upper surface slopes regularly and rapidly from the ambitus to it. The lower surface is concave.

The ambulacra are narrow, the poriferous zones being nearly straight and flush. Each ambulacrum has two rows of primary tubercles imperforate and noncrenulate, which are very much larger at the ambitus than above or below. These tubercles are very rapidly reduced in size on the upper surface and entirely disappear or are replaced by small secondaries as the apical system is approached.

The interambulacra have similar tubercles to those of the ambulacra, the two outer rows only on each area continuing to the apical system.

The apical system is simple and distinct. The peristome is small and the periproct large and of subpentagonal outline.

Related forms.—*C. sloani* is quite distinct from *C. improcerus*, the only other Miocene species known at the present time. It is much higher and has a quite different distribution of the primary tubercles.

Locality.—Basticks Landing, Great Peedee River, S. C.

Geologic horizon.—Miocene.

Collection.—U. S. National Museum (166488).

Suborder ECHININA.

Family TRIPLECHINIDÆ.

Genus PSAMMECHINUS Agassiz.

Psammechinus philanthropus (Conrad).

Plate LXXXIV, figures 6a–c.

Echinus philanthropus Conrad, 1843, Acad. Nat. Sci. Philadelphia Proc., vol. 1, p. 310.
Echinus ruffini Forbes, 1845, Geol. Soc. London Quart. Jour., vol. 1, p. 426, figs. a–d.
Echinus ruffini Forbes, 1845, Geol. Soc. London Proc., vol. 4, p. 560, text figs.
Echinus philanthropus Conrad, 1846, Am. Jour. Sci., 2d ser., vol. 1, No. 2, p. 220.
Psammechinus ruffini Desor, 1858, Synopsis échinides fossiles, p. 121.
Echinus ruffini Emmons, 1858, Agriculture eastern counties—North Carolina Geol. Survey, pp. 306, 307, figs. 239a–d.
Psammechinus philanthropus Meek, 1864, Check list, Miocene, p. 2.
Psammechinus ruffini Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 75.

Determinative characters.—Test small, subhemispherical, tumid at the ambitus, somewhat depressed above, nearly flat below. Ambulacra with two main rows of primary tubercles extending from peristome to apical system, with a thick median row a portion of distance, poriferous zones narrow; pore pairs in triplets in oblique rows. Interambulacra with four regular and two median somewhat irregular rows of subequal primary tubercles at ambitus, the latter reduced toward peristome and apical system. Peristome rather wide, branchial incisions distinct.

Description.—This species which was described by Conrad in 1843 from material secured near Smithfield, Va., was described by Forbes two years later as *E. ruffini*. The test is small and subhemispherical, with a nearly circular ambital outline. It is tumid at the ambitus, somewhat depressed above and nearly flat below, with a slight depression near the peristomial margin.

The ambulacra are rather narrow, the median portion of each area being covered with two main rows of primary tubercles, imperforate and noncrenulate, which extend from the peristome

to the apical system. A third row lies between the other two, and in the larger forms there are additional tubercles that are best developed near the ambitus and do not reach either peristome or apical system. The poriferous zones are narrow, and the pore pairs are found in triplets arranged obliquely.

The interambulacra are covered with tubercles similar to the ambulacra. Six or more rows of primary tubercles occur, four being very regular and two reaching all the way from the peristome to the anal system. The remaining two rows and in some cases additional rows or extra subequal tubercles are chiefly developed at the ambitus. The entire surface of both interambulacra and ambulacra are thickly studded with so many tubercles of about the same size as to give it a very uniform appearance.

The apical system is small. The peristome is rather wide with moderately distinct branchial incisions.

Localities.—James River and York River (type and figured specimen), Va.

Geologic horizon.—Yorktown formation, upper Miocene.

Collections.—Johns Hopkins University (T 1001); Academy of Natural Sciences of Philadelphia.

Psammechinus exoletus McCrady.

Psammechinus exoletus McCrady, 1857, in Tuomey and Holmes, Pliocene fossils of South Carolina, p. 4, Pl. II, fig. 6.
Psammechinus exoletus Meek, 1864, Check list, Miocene, p. 2.
Psammechinus exoletus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 707.

Description.—The fragment briefly described and figured by McCrady is the only material so far as known that has been found representing this species. The description and figure are insufficient to separate with certainty this form from other species.

Locality.—Goose Creek, S. C. (Smith.)

Geologic horizon.—Duplin marl, upper Miocene.

Collection.—Unknown.

Subclass IRREGULARIA.

Order GNATHOSTOMATA.

Suborder CLYPEASTRINA.

Family FIBULARIIDÆ.

Genus SISMONDIA Desor.

Sismondia (?) arnoldi Twitchell, n. sp.

Plate LXXXV, figures 1a–b.

Astrodapsis sp. indet. Arnold, 1909, U. S. Geol. Survey Bull. 396, p. 30, Pl. XXVIII, fig. 5, 5a.
Astrodapsis sp. indet. Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 703.

Description and determinative characters.—This little echinoid, one of the smallest occurring in the Tertiary deposits of the Pacific coast, was first figured but not described by Ralph Arnold, of the U. S. Geological Survey, in whose honor the species is named. The test is very small, being less than half an inch in diameter. In marginal outline it is suboval, with a slight tendency toward the subpentagonal, the anterior end being slightly angulated, the posterior broader and rounded. The whole form is much depressed, slightly convex above, slightly concave below; margin of moderate thickness. Apex central. The ambulacral petals are long, reaching the margin; poriferous zones narrow, diverging in straight lines from apex to margin; pores of both rows round. The whole test is covered with small but rather conspicuous tubercles. The apical system is central, with a conspicuous tumid madreporite. The other details could not be made out on the specimen. The peristome is relatively large, central, subcircular to subpentagonal. The ambulacral grooves appear as rather well defined, simple, straight lines for a short distance out from the peristome, beyond which they become obscure. The periproct is very small, circular, inframarginal, almost marginal.

Dimensions.—Length 10.5 millimeters; width 9.5 millimeters.

Related forms.—*S. arnoldi* resembles *Sismondia* (?) *coalingaensis* and *Scutella* (?) *merriami*, but differs from both in having petals extending to the margin, with straight, diverging poriferous zones.

Locality.—Four miles southeast of northwest end of Kettleman Hills, Coalinga district, California.

Geologic horizon.—Etchegoin formation, upper Miocene and lower Pliocene (?).

Collection.—U. S. National Museum (165538).

SISMONDIA(?) COALINGAENSIS Twitchell, n. sp.

Plate LXXXV, figures 2a–c.

Description and determinative characters.—The test of this species is very small, rarely exceeding one-half inch in length. In marginal outline it is suboval to subovate, broader posteriorly than anteriorly. The whole form much depressed, slightly tumid centrally; margin rather thin. Apex subcentral or slightly excentric posteriorly. Lower surface concave.

The ambulacral petals are subelliptical in outline, extending a little more than halfway to the margin; the posterior pair shorter than the anterior pair; pores round, pairs of pores conjugated. The whole test is covered with small but conspicuous tubercles, scattered irregularly.

The apical system is subcentral or slightly excentric posteriorly, coincident with the apex. The details could not be made out on the specimen studied.

The peristome and ambulacral grooves could not be made out. The periproct is small, inframarginal, almost marginal.

Dimensions.—Length 12 millimeters; width 10 millimeters; height 2 millimeters.

Related forms.—*S. coalingaensis* resembles *Sismondia* (?) *arnoldi* and *Scutella* (?) *merriami*. From the former it differs in having shorter, subelliptical petals and from the latter in lacking the tumid petals and in having a more longitudinally oval marginal outline.

Locality.—Jacalitos Creek, half a mile east of Kreyenhagen's, Coalinga district, California.

Geologic horizon.—Etchegoin formation, upper Miocene and lower Pliocene (?).

Collection.—U. S. National Museum (165717).

Family SCUTELLIDÆ.

Genus SCUTELLA Lamarck.

SCUTELLA ANDERSONI Twitchell, n. sp.

Plate LXXXV, figures 3a–d.

Scutella sp. A., F. M. Anderson 1905, California Acad. Sci. Proc., 3d ser., Geology, vol. 2, No. 2, p. 193, Pl. XIII, fig. 8.

Determinative characters.—Test small; suboval to broadly subovate, broadest posteriorly; margin thin, more so posteriorly than anteriorly, with rather pronounced notches opposite the posterior petals; the whole form greatly depressed, the upper surface ridged along the longitudinal median line, sloping rather steeply away from the ridge to the side edges; apex excentric anteriorly; under surface slightly concave longitudinally. Apical system decidedly excentric anteriorly, about coincident with the apex. Posterior ambulacral petals slightly longer than the anterior paired petals which are slightly longer than the odd petal. Peristome excentric anteriorly. Periproct very small, supramarginal.

Dimensions.—Length 25 millimeters; width 25 millimeters; height 5 millimeters.

Description.—This interesting species was briefly described and figured in 1905 by F. M. Anderson but was not given a specific name. It is here named in honor of Mr. Anderson. The test is small, ranging from less than a half to slightly more than an inch in diameter. In marginal outline it is suboval to broadly subovate; broadest posteriorly, usually about as long as wide. The margin is thin, more so posteriorly than anteriorly, with rather pronounced notches opposite the posterior petals and sometimes with faintly defined notches opposite the anterior paired petals. The whole form is greatly depressed; the upper surface having a more or less well defined ridge extending along the longitudinal median line and involving the odd petal.

the inner ends of the other petals, and the inner portion of the posterior interambulacrum; from the median ridge the surface slopes at first steeply then gradually away to the side edges. The under surface is slightly concave longitudinally. The apex is excentric anteriorly, at the highest point of the median ridge.

The ambulacral areas are rather narrow; the dorsal portions petaloid. The petals are moderate in size, subelliptical, extending more than halfway to the margin, open at the ends, the odd petal more widely open than the others. The poriferous zones are relatively wide, though slightly less so than the interporiferous areas; pores oval, pairs of pores conjugated.

The interambulacral areas are rather broad with the exception of the odd posterior area, which is narrow. The surface of the test is covered with small uniform tubercles.

The apical system is decidedly excentric anteriorly, about coincident with the apex. There is a large, subcircular madreporite, four large genital pores, of which the anterior pair are somewhat nearer together than the posterior pair, and five small radial plates each perforated by a minute pore.

The peristome is excentric anteriorly. The character of the ambulacral furrows can not be made out on the specimens studied.

The periproct is very small, circular and supramarginal, almost marginal.

Related forms.—*S. andersoni* is readily distinguished from all other American scutellas by its longitudinally ridged upper surface, its longitudinally concave lower surface, and its pronounced marginal notches opposite the posterior paired petals.

Localities.—West of Coalinga (Anderson), and Devils Den district, Kern County (figured specimen), Cal.

Geologic horizon.—Tejon formation, upper Eocene; Vaqueros sandstone, lower Miocene.

Collections.—U. S. National Museum (165719); California Academy of Sciences.

Scutella fairbanksi Pack.

Plate LXXXV, figures 4–6.

?*Scutella gabbi* Merriam, 1899, California Acad. Sci. Proc., 3d ser., Geology, vol. 1, No. 5, p. 168, Pl. XXII, figs. 5, 5a.
Scutella fairbanksi (Merriam, MS.) Arnold, 1907, U. S. Nat. Mus. Proc., vol. 32, p. 542, Pl. XLII, fig. 3, Pl. XLIII, fig. 3. No description.
Scutella fairbanksi Eldridge and Arnold, 1907, U. S. Geol. Survey Bull. 309, pp. 13, 17, 230, 232, Pl. XXIX, fig. 3, Pl. XXX, fig. 3. No description.
Scutella fairbanksi Pack, 1909, Univ. California Dept. Geology Bull., vol. 5, No. 18, pp. 276–277, Pl. XXIII, fig. 1.
?*Scutella merriami* Arnold, 1909, U. S. Geol. Survey Bull. 396, Pl. VI, fig. 4. Figure only.
?*Scutella merriami* Arnold and R. Anderson, 1910, U. S. Geol. Survey Bull. 398, Pl. XXVIII, fig. 4. Figure only.
Echinarachnius fairbanksi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 703.

Determinative characters.—Test medium in size; subcircular, transversely oval or broadly subovate, slightly broader than long; margin markedly thin and faintly undulating, submarginal area wide; the whole form greatly depressed, the upper surface rising gradually and very gently from the margin to the low central or subcentral apex; under surface flat or nearly so. Apical system central or slightly excentric anteriorly and about coincident with the apex. Ambulacral petals relatively short, subequal in size, subsymmetrical as a group; the odd petal differing from the rest in having its inner row of pores diverging gradually to the end, which is wide open, much more so than in the other petals. Peristome central or subcentral; main ambulacral furrows deep and probably simple and straight for most of the distance to the margin, then branching. Periproct very small, supramarginal.

Dimensions.—Specimen A (type): Length 53 millimeters; width 49 millimeters (Pack). Specimen B: Length 33 millimeters; width 36 millimeters.

Description.—This new Californian Scutella has a test which is of medium size, ranging from about 1 to 2½ inches in diameter. In marginal outline it is somewhat variable, being sometimes subcircular, sometimes transversely oval, sometimes broadly subovate. The margin is markedly thin and faintly undulating, submarginal area wide. The whole form is greatly depressed; the upper surface rising gradually and very gently from the margin to the low, central or subcentral apex. The under surface is flat or nearly so.

The ambulacral areas are rather wide at the margin, where they equal or exceed the interambulacral areas, widening rapidly from the ends of the lateral and posterior petals [illegible] from the odd petal; dorsal portions petaloid. The petals are relatively short, almost [illegible] as a group, almost equal in size, extending from one-half to almost two-thirds the way to the margin, all but the odd petal subelliptical in outline, tending to close at the ends; the odd petal noticeably differs from the rest in form, having its inner rows of pores diverging gradually to the end, which is wide open, much more so than that of the other petals. The poriferous zones are relatively wide; pores oval; pairs of pores conjugated; interporiferous areas of the anterior paired and posterior petals rather narrow, not much wider than the poriferous zones, that of the odd petal considerably wider, especially at the outer end of the petal. Several pairs of pores, in strongly diverging rows, extend beyond the ends of the petals.

The interambulacral areas are all rather narrow between the petals, broad from about opposite the ends of the petals to the margin. The surface of the test is covered with small uniform tubercles, which are somewhat larger on the under surface, especially near the peristome.

The apical system is central or slightly excentric anteriorly and about coincident with the apex. The details are obscure on the specimens, but there are four large genital pores of which the two anterior are nearer together than the posterior pair.

The peristome is central, or subcentral, slightly depressed; ambulacral furrows, according to Pack, are "deep and traceable to the margin," where they "show a slight tendency to branch." On the specimens studied they are not well shown.

The periproct is very small, supramarginal; sometimes located at a distance from the edge equal to its own diameter.

Related forms.—*S. fairbanksi* is most closely related to *S. gabbi* (Rémond) Merriam, but differs from it, according to Pack, in "attaining a greater size, in having a slightly undulating marginal outline, in having deeper and better marked furrows on the actinal surface, and in having the anal pore entirely upon the upper surface." *S. fairbanksi* is also allied to *Dendraster interlineatus* and *D. oregonensis*, but may be easily separated from both by its more central apical system, shorter and more equal petals, and wider marginal area. It also differs from *D. oregonensis* in having the posterior poriferous zones of its paired petals curving.

The specimen figured by Arnold as *Scutella merriami* was probably a young specimen of *S. fairbanksi*.

Localities.—Near Torrey Canyon wells, southwest of Piru, Ventura County, Cal. (Arnold); Sespe Canyon, Ventura County, Cal. (Pack, Arnold).

Geologic horizon.—Vaqueros formation, lower Miocene.

Collections.—U. S. National Museum (164963, B, C); University of California (A).

Scutella (?) merriami (Anderson).

Plate LXXXV, figures 7a–c, 8a–b.

Astrodapsis merriami F. M. Anderson, 1905, California Acad. Sci. Proc., 3d ser. Geology, vol. 2, No. 2, pp. 193–194, Pl. XIV, figs. 33, 34.
Scutella merriami Arnold, 1909, U. S. Geol. Survey Bull. 396, p. 18.
?*Scutella merriami* Arnold, 1909, figure, U. S. Geol. Survey Bull. 396, Pl. VI, fig. 4.
Scutella merriami Arnold and R. Anderson, 1910, U. S. Geol. Survey Bull. 398, pp. 85, 86, 87.
?*Scutella merriami* Arnold and R. Anderson, 1910, figure, U. S. Geol. Survey Bull. 398, Pl. XXVIII, fig. 4.
Sismondia merriami Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 702.

Description.—This little echinoid was first described and figured by F. M. Anderson in 1905. Its button-like appearance and its abundance in certain deposits in the Coalinga district of California have led to these deposits being designated Button beds. The writer has had about 20 specimens from the Button beds available for study, most of which probably belong to this species; but most of them were in poor condition and as the type could not be secured for comparisons the description of F. M. Anderson is here given verbatim:

Disk small, circular, depressed; margin only slightly notched at the ambulacral extremities; apex central, only slightly elevated, star symmetrical, petals equal but not reaching the margin of the disk, and slightly elevated; anal

pore marginal; ambulacral furrows of inferior surface straight and simple. The largest specimens have a diameter of 1½ inches, though the usual size is three-fourths of an inch. The disk is thin and flattened but shows a decided tendency to form elevated stars on the upper surface.

The writer's study of the specimens from the Button beds already referred to suggests a few comments in connection with this description. The size of the specimens studied ranged from 8 to 15 millimeters in diameter. The marginal outline was usually circular, but sometimes longitudinally oval. The marginal notches are often hardly discernible. The petals extend from half to two-thirds the way to the margin. In some specimens the petals were practically flush with the surface and in some were slightly tumid. In some the poriferous zones of all the petals diverge continuously and are wide open at the ends, though the odd petal is somewhat more widely open than the rest; in others those of all but the odd petal are partly closed, as in the form figured by Anderson. In the form figured by Arnold (which has been examined by the writer) the poriferous zones of all but the odd petal diverge for about half their length, then converge to a less degree so that at their ends they are only slightly nearer together than midway, those of the odd petal diverging continuously to their ends, where they are far apart, the inner lines of pores forming a well-defined V. In view of the variations indicated it seems probable that among the small echinoids of the Button beds there are several forms, possibly distinct species, which closely resemble each other in general appearance, while differing in details. The lines between these forms can only be drawn by one who has access to the type and to an extensive series of good specimens. However, the writer is of the opinion that, in view of Anderson's significant remark that the test "shows a decided tendency to form elevated stars on the upper surface," the small buttonlike forms with slightly tumid petals are most typical of the species *S. merriami*. Some of the larger specimens assigned to *S. merriami*—such as the one figured by Arnold—strongly resemble *Scutella fairbanksi* and, with further collecting and comparative study with the types of the forms involved in hand, may prove to be young specimens of that species. Aside from its smaller size, the only important apparent difference between Arnold's figured form and *S. fairbanksi* is that the periproct is exactly marginal, visible from above and below; but it may be found that *S. fairbanksi*, which is somewhat variable in regard to this feature, may vary enough to include forms with a marginal periproct.

There is some doubt in regard to the generic position of the present species. There seems to be no good ground for placing it in the genus Astrodapsis, as it lacks the depressed apical system and deeply impressed interambulacral areas characteristic of that genus. Anderson says that the ambulacral furrows are straight and simple, which, if true, would suggest placing it in the genus Sismondia, but on the other hand in the figure of the under surface given by Anderson the furrows appear to be simple and straight for about two-thirds of the way to the margin and then bifurcate symmetrically, which fact points toward the genus Scutella. It is not improbable that both genera may be represented. The ambulacral furrows are not discernible upon the specimens studied by the writer, and the form is therefore, for the present, placed doubtfully in the genus Scutella.

Localities.—Tar Springs, Kreyenhagen's and Temblor, Mount Diablo Range, California (F. W. Anderson); Garza Creek gorge in Reef Ridge, Canoas Canyon, near Hugo Kreyenhagen's place, and 8½ miles north of Coalinga, all in the Coalinga district, California (Arnold); Wagon-wheel Mountain, Devils Den district, Kern County, Cal. (Arnold).

Geologic horizon.—Vaqueros formation, lower Miocene. Occurs in the Button beds, which are near the middle of the formation.

Collections.—U. S. National Museum (165584, B; 165716, A); California Academy of Sciences; F. M. Anderson.

Scutella norrisi Pack.

Plate LXXXV, figure 9.

Scutella (?) *norrisi* Pack, 1909, Univ. California Dept. Geology Bull., vol. 5, No. 18, pp. 277–278, Pl. XXIII, fig. 3.
Echinarachnius norrisi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 703.

Description.—Since no opportunity has been had of studying any specimen of this species the description of Pack is given verbatim:

Test subcircular in general outline, with deep, broad, marginal notches in the edges of the ambulacral areas. The two posterior notches are much deeper than are the anterior ones, and truncate the posterior interambulacral space on either side of the median line, shaping the posterior end of the test into a prominent process. The test when viewed from above has a leaf-like appearance. Test much depressed, edges markedly thin, abactinal surface very slightly arched, apex central; actinal surface flat or gently concave. Mouth central, slightly sunken; ambulacral furrows poorly shown in the specimens examined, but evidently branch but little, if at all. Main ambulacral grooves continue from the mouth to the margin, entering the marginal notches. Anal pore small, inframarginal. Ambulacral star central. Petals extend about three-fourths the distance to the margin and not entirely closed at the ends.

Dimensions.—Longitudinal diameter, 55 millimeters.

As only a single figure of this form is given by Pack,[1] and as that too is one of the under surface of a weathered specimen, it is hardly possible to discuss the form intelligently. However, it may be said that the marginal outline, with its five large ambulacral notches alternating with broad, blunt, rounded projections differentiates the form from all other known Californian echinoids. From the description and figure the form appears to be a Scutella. The resemblance of the present species to *Astrodapsis whitneyi* which Pack remarks upon in connection with his description of *A. antiselli* is but a slight one, as the notches of *A. whitneyi* are not nearly as large.

Localities.—Five miles northwest of the Stone Canyon coal mine, Monterey County, and at San Juan River near La Panza, San Luis Obispo County, Cal.

Geologic horizon.—Vaqueros formation, lower Miocene.

Collection.—University of California.

Scutella aberti Conrad.

Plate LXXXVI, figures 1a–b; Plate LXXXVII, figures 1a–d.

Scutella aberti Conrad, 1842, Nat. Inst. Promotion Sci. Proc., 2d Bull., p. 194, no figure.
Scutella alberti Bronn, 1848, Index palæontologicus, vol. 1, p. 1125, vol. 2, p. 196.
Scutella alberti Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Scutella alberti Dall, 1892, U. S. Geol. Survey Bull. 84, p. 52.
Scutella aberti Clark, 1904, Maryland Geol. Survey, Miocene, p. 432, Pl. CXXIX, figs. 2, 2a, and Pl. CXX, figs. 1a, 1b, 2a, 2b.
Scutella aberti Clark, 1906, Maryland Geol. Survey Rept., vol. 6, p. 258, Pl. XXII, fig. 17.
Scutella aberti Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 705.

Determinative characters.—Test large to very large, subcircular to subquadrate in marginal outline, the whole form much depressed, less so within the large petaloidal area where it rises in the form of a low, broad mound whose flattened summit is excentric anteriorly, margin relatively thin, with three large, broad notches in the posterior border, between which the test extends in the form of two large, broad, blunt projections; under surface flat. Ambulacral petals very large, subspatulate, extending more than two-thirds the way to the margin. Apical system slightly excentric anteriorly but less so than the apex. Peristome small, subpentagonal, ambulacral furrows simple and straight for a short distance from the peristome, then forking, the branches proceeding somewhat sinuously and divergingly to the margin. Periproct very small, subcircular, inframarginal, near the head of the pointed central notch in the posterior border.

Dimensions.—Length 120 millimeters; width 121.5 millimeters; height 14 millimeters. The largest specimen examined was 178 millimeters in diameter.

Description.—This species, the largest of American Scutellas, was first reported in 1842 by Conrad, who described but did not figure it, and who named it after Col. J. J. Abert, of Washington, D. C. It was first figured by Clark in 1904. The form has been but little known owing to its limited distribution and to the obscure and out of the way character of the publication in which Conrad's description was published. Perfect specimens are rare; imperfect ones and fragments are very abundant in the thin bed in which it occurs and to which it appears to be restricted. It is not known positively to occur outside of Maryland. Several authors have

[1] Since the above description was written Pack has published additional details regarding *Scutella aberti*, based on recently discovered material (Univ. California Dept. Geology Bull., vol. 7, No. 13, pp. 299–300, Pl. XV, fig. 1). The new material establishes, as Pack postulates, the new species, which is unlike all other California scutellid forms.

given the name of the form as *S. alberti* instead of *S. aberti*, as it should be. The test is large to very large in size, ranging from 90 millimeters to about 180 millimeters in diameter. In marginal outline it is subcircular to subquadrate, broader posteriorly than anteriorly, sometimes very noticeably so. The whole form is much depressed although more so around the margin, within the large area covered by the ambulacral petals it rises in the form of a low broad gently rounded mound which varies in height from about ½ to about ¾ inch, and the summit of which is flattened and excentric anteriorly. The margin of the test is relatively thin and undulating; with a faint, broad, shallow curved notch opposite each of the three anterior petals, two large, broad, deep, curved notches opposite the posterior pair of petals and one large, broad, deep, pointed notch in the middle of the posterior edge. Between the large central notch and each of the large curved notches the test extends in the form of a large, broad, blunt projection; the two projections and three large notches together forming the whole posterior border of the test. The under surface is flat. The apex is decidedly excentric anteriorly, at the summit of the tumid central area.

The ambulacral areas are narrow in the petaloid region, but very broad in the margina region, where they are considerably wider than the interambulacral areas. The dorsal portions of the ambulacra are petaloid. The petals are very large, subequal in length, the posterior pair being somewhat longer than the others; subspatulate to Indian-club shape in form; nearly closed at the ends; extending more than two-thirds the way from the center to the margin. The poriferous zones are wide, wider than the interporiferous areas; the inner row of pores oval, outer row slitlike, pairs of pores conjugated, the groove lines continuing beyond the inner row of pores to the center of the interporiferous areas, and the spaces between the grooves very narrow.

The interambulacral areas are broad near the ends of the petals, but become narrower toward both center and margin. The plates are polygonal and are very large, especially those on the under surface. Single plates are often found in a more or less weathered condition showing on both their upper and under surfaces numerous grooves and ridges. The whole surface of the test is covered with small uniform tubercles which are slightly larger on the under surface.

The apical system is relatively large, slightly excentric anteriorly, on the flattened surface posterior to the apex of the test. The madreporite is relatively large, subpentagonal, occupying the larger part of the area covered by the system and flush with the surface. There are five small genital pores near the points of the madreporic pentagon and five small triangular radial plates each perforated by a very small elliptical pore.

The peristome is relatively small, subcircular to subpentagonal, subcentral; the ambulacral furrows simple and straight for a short distance from the peristome, then forking and diverging nearly symmetrically, each pair of branches proceeding in a more or less sinuous course and without branching for over half the way to the margin, then branching considerably, the branches being given off on the inside of the more important furrow, which continues to diverge more and more as the margin is approached.

The periproct is both relatively and actually very small, subcircular, inframarginal, a short distance in from the point of the large, central notch in the posterior border.

Related forms.—This species is not closely allied to any other American form. It bears a superficial resemblance to *Periarchus lyelli* and *P. altus* but is readily separated from each of them by the character of its ambulacral furrows, its inframarginal periproct, and the large projections and notches in its posterior margin. It is similar in general features to two foreign forms—*S. subrotunda* Lamarck,[1] from the lower Miocene of Bordeaux, France, and *S. tarraconensis* Lambert, from the Burdigalien Miocene of Barcelona, Spain. From each, however, it can be easily distinguished by its much more pronounced posterior notches and projections and by its less central apex.

Localities.—Jones Wharf, St. Marys County, (figured specimen), Governor Run, Calvert County, and Dover Bridge, Dorchester County, Md.

[1] Agassiz's monograph Des scutelles, pp. 76–78, Pl. XVII, figs. 1–9. Desor, in Synopsis des échinides, p. 232, says that *S. subrotunda* Lamarck is from the lower Miocene.

Geologic horizon.—Choptank formation, middle Miocene.

Collections.—Maryland Geological Survey; Johns Hopkins University; U. S. National Museum; Academy of Natural Sciences of Philadelphia.

Scutella gabbi (Rémond) Merriam.

Plate LXXXVIII, figure 1a–b.

?*Clypeaster gabbi* Rémond, 1863, California Acad. Sci. Proc., vol. 3, pp. 53, 54, no figure. See description on page 211 of the present work.
?*Clypeaster gabbi* Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
?*Clypeaster gabbi* Gabb, 1869, Geol. Survey California, Paleontology, vol. 2, pp. 36, 109, Pl. XII, figs. 64, 64a.
?*Clypeaster gabbi* Cooper, 1888, Cat. California fossils: State Mineralogist Seventh Rept., p. 271.
Scutella gabbi Merriam, 1899, California Acad. Sci. Proc., 3d ser., Geology, vol. 1, No. 5, p. 168, Pl. XXII, figs. 5, 5a.
Echinarachnius gabbi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 703.

Description.—The writer has been unable to obtain any specimens [1] of this form. The description of Merriam will therefore be repeated verbatim:

> Test circular, much depressed, margin thin. Average specimens 25 to 30 mm. in diameter, largest specimens ranging up to 40 and 45 mm. in diameter.
>
> Petals short, not extending more than two-thirds of the distance to the margin; excepting the anterior one, they are nearly closed at the ends. Anterior petal wide open. Except in the anterior area the ambulacral plates suddenly enlarge and the area rapidly widens beyond the ends of the petals. In these areas, pairs of small, round pores, diverging strongly from the ends of the petals, may be present almost to the margins. In the anterior petal the plates do not enlarge as noticeably toward the margin as in the others, neither do the more persistent pore pairs diverge as much.
>
> Apical shield with four genital pores, there being none at the end of the posterior interambulacral area. Anus marginal to supramarginal; in quite a number of specimens it is found to be entirely on the upper surface. No marked difference is noticeable between the tubercles of the upper and lower surfaces.
>
> The ambulacral furrows of the actinal surface are not usually well preserved and have been clearly seen on only a few specimens; they divide dichotomously a little less than half way to the margin.

Related forms.—The form described and figured by Merriam differs in several respects from that originally described by Rémond. Rémond's was subelevated, comparatively thick and with margin rounded. Merriam's is much depressed, and with margin thin. The petals of Rémond's form were elongated and open at their extremities—those of Merriam are short and, excepting the anterior one, are nearly closed at the ends. In Rémond's form the ambulacral furrows are straight, which led to his placing the form in the genus Clypeaster; in Merriam's the furrows divide dichotomously a little less than half way to the margin, which indicates a Scutella. These differences are too important to be ignored and raise the question whether Merriam has described and figured identically the same form as Rémond. The location of Rémond's type is unknown and he failed to give any figures; but his other work is of too high an order to justify any radical departure from his description, and his form is therefore placed in the synonomy of the present species with an interrogation mark as indicative of the doubt that exists in regard to the matter. It is not at all improbable that the investigator who obtains considerable material from Rémond's locality, San Pablo Bay, south of Mare Island, Cal., may discover a form more nearly corresponding to Rémond's description than the one here described.

Merriam's *Scutella gabbi* is most closely related to *S. fairbanksi*, which, however, differs, according to Pack, in "attaining a greater size, in having a slightly undulating marginal outline, in having deeper and better marked furrows on the actinal surface, and in having the anal pore entirely upon the upper surface."

Localities.—San Pablo Bay (Rémond, Gabb, Merriam, Weaver; Walnut Creek (Gabb, Weaver); and Martinez (Gabb), Cal.

Geologic horizon.—San Pablo formation, upper Miocene. Merriam states that it occurs in the lowest beds of the San Pablo formation.

Collection.—University of California (19425).

[1] Since this description was written [illegible] was lent to the writer by Merriam. [illegible] doubt as to its being the same form as that described by Rémond. [illegible] regard Merriam's *S. gabbi* as [illegible] the same as *S. fairbanksi* Pack.

Genus DENDRASTER Agassiz emend.

Dendraster L. Agassiz, 1847, Cat. raisonné échinodermes; Soc. Nat. Ann., vol. 7, p. 135.
Echinarachnius A. Agassiz, 1872 (subgenus) pars, Revision of the Echini, Mus. Comp. Zoology Illus. Cat. 7, pp. 107, 524.
Echinarachnius Duncan, 1891 (subgenus) pars, Revision genera and great groups Echinoidea, p. 158.
Echinarachnius Grabau and Shimer, 1910, North American index fossils, p. 592.

The genus Dendraster as used here is that of Agassiz with a slight amendment enlarging it. It is here regarded as including the Scutella-like forms having a decidedly posteriorly excentric apical system, very unequal petals, ambulacral furrows bifurcating near the peristome, and the periproct inframarginal, marginal, or supramarginal. The species *D. excentricus* is the type of the genus.

Some confusion exists in regard to the forms included in the present genus by reason of the use of the generic term Echinarachnius by some authors as a subgenus of Scutella for the forms having an excentric apical system. Duncan is partly responsible for this, having proposed it in his revision of the Echinoidea. In Eastman's translation of Zittel's Paleontology the suggestion of Duncan was carried out, and in Grabau and Shimer's "Index fossils of North America" more positive action was taken by divorcing Echinarachnius from Scutella and still ascribing it, and basing it essentially upon, the excentric apical system.

The genus Echinarachnius was established by Leske in 1778, what is evidently his type species being *Echinus placenta* Linné. Neither this species nor any of the allied forms he incidentally mentioned had an excentric apical system. The species *placenta* is now recognized (though with doubtful propriety) as the type of the genus Arachnoides Klein. (See p. 124.) Gray, in 1825, redrew and enlarged Echinarachnius Leske, retaining *placenta* as the type species and adding *Scutella parma* Lamarck and *Scutella lenticularis* Lamarck, neither of which has an excentric apical system. A. Agassiz, in 1872, reduced Echinarachnius to the rank of a subgenus under Scutella; distinguishing it chiefly by having "interior pillars more or less concentric with the edge," and including both forms with central apical system, *E. parma*, and excentric apical system, *E. excentricus*. In view of these facts it is difficult to see any grounds for the use of the name Echinarachnius for forms with an excentric apical system.

As a result of the discovery in California deposits of many specimens, including several new species, having an excentric apical system, the writer has been led to differ with A. Agassiz and regards the excentricity of the apical system as a fundamental and satisfactory basis of separation and therefore regards the genus Dendraster L. Agassiz as well founded. Stefanani[1] appears to have come to the same conclusion.

DENDRASTER PERRINI (Weaver).

Plate LXXXVIII, figures 2, 3a–c.

Scutella perrini Weaver, 1908, California Univ. Dept. Geology Bull., vol. 5, No. 17, p. 273, Pl. XII, fig. 2.
Astrodapsis perrini Rathbun, 1908, U. S. Nat. Mus. Proc., vol. 35, p. 342. Listed on authority of R. Arnold and erroneously ascribed to Merriam.
Scutella perrini Arnold, 1909, U. S. Geol. Survey Geol. Atlas, Santa Cruz folio (No. 163), p. 6.
Scutella perrini Arnold, 1909, U. S. Geol. Survey Bull. 396, pp. 30, 34, 38, 162, Pl. XXVIII, figs. 1, 2.
Echinodiscus (?) *perrini* Lambert, 1909, Rev. crit. paléozoologie, vol. 13, p. 122.
Scutella perrini Arnold and Anderson, 1910, U. S. Geol. Survey Bull. 398, p. 338, Pl. L, figs. 1, 2.
Merriamaster perrini Lambert, 1911, Rev. crit. paléozoologie, vol. 15, p. 64.
Merriamaster perrini Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 704.

Determinative characters.—Test medium in size; usually circular rarely longitudinally oval in marginal outline, broadest centrally; upper surface greatly depressed, slightly convex, rising gradually from the unusually thick margin to the low apex which is slightly excentric anteriorly; under surface concave. Tubercles conspicuous, nearly equally so over the whole test; not close together. Apical system excentric posteriorly, from about one-sixth to about one-fifth the radius from the center. Ambulacral petals large, wide, broadly subelliptical, all of them extending nearly to the margin, wide open at the ends; interporiferous areas very wide, sometimes faintly tumid, the posterior paired petals shorter than the others, though less so than in

[1] Stefanani, G., Soc. geol. italiana Boll., vol. 33, p. 704.

allied forms and less divergent than the anterior pair. Peristome small, slightly excentric posteriorly; ambulacral furrows straight and simple for a short distance from the peristome, then forking, the branches diverging and extending nearly to the margin. Periproct very small, circular, inframarginal, nearly marginal.

Dimensions.—Largest specimen studied: Length 58 millimeters; width 58 millimeters; height 10 millimeters. Specimen A: Length 46 millimeters; width 43 millimeters; height 9 millimeters. Specimen B: Length 45 millimeters; width 43 millimeters; height 9 millimeters.

Description.—The test of this recently described Californian species is medium in size, ranging from about 1½ to nearly 2½ inches in diameter. In marginal outline it is usually circular, though sometimes longitudinally oval; broadest opposite the middle. The upper surface is greatly depressed, slightly convex, rising gradually from the margin to the apex, which is low, and slightly excentric anteriorly. The margin is unusually thick for a scutellid form and the submarginal area beyond the ends of the petals is very narrow. The under surface is concave; the concavity gradually increasing from the margin to the peristome, where it is from a fourth to a third of the height of the test.

The ambulacral areas are wide, widest at the margin where they are wider than the interambulacral areas; dorsal portions petaloid. The petals are large, the total area covered by them being greater relatively than in most related forms, wide, and widening rapidly near the apical system; broadly subelliptical in outline; the anterior pair longer than the posterior pair though less so than in allied forms, the odd petal slightly longer than the anterior pair, all of them extending nearly to the margin and wide open at the ends; the posterior pair less divergent than the anterior pair. The poriferous zones are of moderate width, pores oval; pairs of pores conjugated. The interporiferous areas are unusually wide, from three to four times as wide as the poriferous zones and sometimes faintly tumid on unweathered specimens.

The interambulacral areas are rather narrow and nearly equal in width between the petals, wide at the margin. The whole surface of the test, including the margin and the interporiferous areas, is covered with perforate tubercles which are relatively larger and more conspicuous than in most related forms and which project above the edges of the wide scrobicules in which they are placed. The tubercles are only slightly larger on the under than on the upper surface and they are not very close together.

The apical system is excentric posteriorly, though less so than in most related forms, being situated from about one-sixth to about one-fifth the distance from the center to the posterior margin. There is a large subpentagonal madreporite, four genital pores situated at the points of the pentagon, the anterior two being nearer together than the posterior two, and five small radial plates each perforated by a minute pore.

The peristome is small, circular, slightly excentric posteriorly just beneath the apical system; ambulacral furrows straight and simple for a short distance from the peristome, then forking, the branches diverging and extending almost to the margin.

The periproct is very small, circular, inframarginal, nearly marginal.

Related forms.—*D. perrini* is closely related to *D. arnoldi*, but can be separated from it by its larger petaloidal area, its wider and less tumid interporiferous areas, its broader and less gradually widening petals, and its relatively longer posterior petals.

In its circular form and its thick margin *D. perrini* presents an interesting resemblance to *Mortonella quinquefaria*, but is easily separated by its posteriorly excentric apical system, its relatively larger petalloidal area and narrower submarginal area, and by the inframarginal position of its periproct.

Lambert's genus Merriamaster is not recognized, as it is based on the erroneous idea that the ambulacral furrows are simple as in Laganum.

Locality.—Zapato Creek, one-half mile south of A. Kreyenhagen's place, Coalinga district, California.

Geologic horizon.—Etchegoin formation (apparently limited to the upper portion), upper Miocene and lower Pliocene (?).

Collections.—U. S. National Museum (165560, A, B); University of California.

Dendraster arnoldi Twitchell, n. sp.

Plate LXXXVIII, figures 4a–d.

Astrodapsis? sp. *a* Arnold, 1909, U. S. Geol. Survey Bull. 396, p. 162, Pl. XXVIII, figs. 3, 3a.
Astrodapsis? sp. *a* Arnold, 1910, U. S. Geol. Survey Bull. 398, p. 338, Pl. L, figs. 3, 3a.

Determinative characters.—Test small to medium in size; subcircular to broadly oval in marginal outline, usually longitudinally elongate, more rarely transversely elongate, broadest centrally; upper surface greatly depressed, slightly convex, rising gradually from the moderately thick margin to the low, central apex; under surface concave. Tubercles crowded and conspicuous, notably so within the interporiferous areas and between the ambulacral furrows. Apical system excentric posteriorly, from about one-fifth to about one-fourth the radius from the center. Ambulacral petals of medium size, extending from one-half to two-thirds the way to the margin, wide open at the ends, moderately wide; interporiferous areas notably tumid; the posterior paired petals decidedly shorter than the rest and relatively shorter than in closely related forms. Peristome small, central or subcentral; ambulacral furrows straight and simple for a short distance from the peristome, then forking, the branches diverging and extending nearly to the margin. Periproct very small, circular, inframarginal, nearly marginal.

Dimensions.—Type specimen: Length 45 millimeters; width 43 millimeters; height 7 millimeters. Small, transversely elongate specimen: Length 22.5 millimeters; width 24 millimeters; height 5 millimeters.

Description.—This species is found in association with *D. perrini* and *D. coalingaensis* in the Etchegoin formation of California. It is rather an abundant form. A number of specimens were collected by Dr. Ralph Arnold, of the United States Geological Survey, and one was figured by him. The species is therefore named in his honor. The writer found several specimens among the material studied which showed bifurcating ambulacral furrows, thus proving the form to be allied to Scutella, instead of belonging to Astrodapsis, the genus to which Arnold doubtfully referred the form he figured. The test of this species is small to medium in size, ranging from less than one-half to nearly 2 inches in diameter. In marginal outline it is subcircular to broadly oval, usually longitudinally elongate more rarely transversely elongate, broadest opposite the middle or slightly to the rear of the middle. The upper surface is greatly depressed, slightly convex, rising gradually from the margin to the apex, which is low and central or subcentral. The margin is of moderate thickness, though somewhat variable, sometimes approaching the thickness of that of *D. perrini*. The under surface is concave, the concavity gradually increasing from the margin to the peristome.

The ambulacral areas are wide, widest at the margin, where they are wider than the interambulacral areas; dorsal portions petaloid. The petals are of medium size, moderately wide and tending to widen gradually to near their distal ends, extending from one-half to two-thirds the way to the margin, the anterior pair decidedly longer than the posterior pair, the odd petal slightly longer than the anterior pair; more subspatulate than subelliptical in outline; wide open at the ends. The poriferous zones are wide, pores oval, pairs of pores conjugated. The interporiferous areas are rather wide, usually from two to three times the width of the poriferous zones, and notably tumid.

The interambulacral areas are rather narrow between the petals, wide at the margin. The whole surface of the test is covered with tubercles which are crowded and relatively conspicuous, projecting above the edges of the rather wide scrobicules and being especially conspicuous within the interporiferous areas and between the ambulacral furrows.

The apical system is excentric posteriorly, situated from about one-fifth to about one-fourth the distance from the center to the posterior margin. The madreporite is large and there are four genital pores, the anterior two being nearer together than the posterior two, and five small radial plates each perforated by a minute pore.

The peristome is small, subcircular, central, or subcentral; ambulacral furrows straight and simple for a short distance from the peristome, then forking, the branches diverging and extending nearly to the margin.

The periproct is very small, circular, inframarginal, nearly marginal.

Related forms.—*D. arnoldi* is closely related to *D. perrini*, but can be separated from it by its smaller petaloidal area and broader submarginal area, its relatively shorter posterior petals, its narrower interporiferous zones, and its narrower and less [illegible] is liable to be confused with *D. coalingaensis* at times, but is to be distinguished from the latter by its thicker margin, less symmetrically elliptical petals wide open at the ends, its more conspicuous tubercles, and its less posteriorly excentric apex.

Localities.—Near A. Kreyenhagen's place and south of Lucile Well, 2 miles southwest of Coalinga in Coalinga district, California.

Geologic horizon.—Etchegoin formation, upper Miocene and lower Pliocene (?).

Collection.—U. S. National Museum (165707).

Dendraster gibbsii (Rémond).

Plate LXXXIX, figs. 1a–b, 2–4; Plate CVIII, *B*.

Scutella gibbsii Rémond, 1863, California Acad. Sci. Proc., vol. 3, pp. 13, 14.
Scutella gibbsii Meek, 1864, Smithsonian Misc. Col., vol. 7 (183), p. 2.
Scutella gibbsii Gabb, 1869, Geol. Survey California, Paleontology, vol. 2, pp. 37, 109, Pl. XIII, figs. 66, 66a.
Scutella gibbsii Cooper, 1888, Cat. California fossils, State Mineralogist Seventh Rept., p. 271.
Echinarachnius gibbsii Merriam, 1899, California Acad. Sci. Proc., 3d ser., Geology, vol. 1, No. 5, p. 169, Pl. XXII, fig. 7.
?*Scutella gibbsii* F. Anderson, 1905, California Acad. Sci. Proc., 3d ser., Geology, vol. 2, p. 180.
Echinarachnius ashleyi (Merriam, MS), Arnold, 1907, U. S. Geol. Survey. Bull. 322, Pl. XXIV, figs. 6, 7.
?*Echinarachnius excentricus* Eschscholtz var. Arnold and Anderson, 1907, U. S. Geol. Survey Bull. 322, Pl. XXIV, fig. 8. This is apparently a somewhat variant form of *Dendraster gibbsii*.
Echinarachnius gibbsii Arnold, 1909 (pars), U. S. Geol. Survey Bull 396, pp. 24, 25, 27, 31, 34 (pars); 38, 42 (pars), 132, 144, 146; Pl. XIII, figs. 1, 2; Pl. XIX, figs. 1, 2; Pl. XX, fig. 7.
non *Echinarachnius gibbsii* Arnold, 1909, (pars), U. S. Geol. Survey Bull. 396, pp. 34 (pars), 42 (pars), 162; Pl. XXVIII, figs. 4, 4a.
Echinarachnius gibbsii Arnold and R. Anderson, 1910 (pars), U. S. Geol. Survey Bull. 398, pp. 316, 318; Pl. XLI, figs. 1, 2; Pl. XLII, fig. 7.
non *Echinarachnius gibbsii* Arnold and R. Anderson, 1910 (pars), U. S. Geol. Survey Bull. 398, p. 338; Pl. L, figs. 4, 4a,
Dendraster ashleyi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 706.
Dendraster gibbsii Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 704.

Determinative characters.—Test small to large, suboblong, subquadrate, suboval, or subovate in marginal outline, length usually equal to or greater than width, though sometimes considerably less, usually broadest back of the center; upper surface convex, much depressed, though less so posteriorly than anteriorly, rising directly from the thin margin to the low, posteriorly excentric apex; undersurface flat. Apical system very excentric posteriorly, from one-third to more than one-half the radius from the center. Ambulacral petals large, all but the odd petal approaching rather close to the margin; the posterior pair shorter than the others, more divergent than the anteriorly curving anterior pair and with widely divergent poriferous zones. Peristome small, excentric posteriorly, though less so than apical system; ambulacral furrows fork near the peristome, the branches at first diverging then converging slightly and proceeding nearly to the margin, giving off only a few branches. Periproct very small, circular, inframarginal, nearly marginal.

Dimensions.—Specimen A (Pl. LXXXIX, figs. 1a, 1b): Length 62 millimeters; width 59 millimeters; height 13 millimeters. Specimen B (Pl. LXXXIX, fig. 2): Length 87 millimeters; width 81 millimeters; height 11 millimeters. Specimen C (Pl. LXXXIX, fig. 3): Length 81 millimeters; width 95 millimeters; height 16 millimeters. Specimen D (Pl. LXXXIX, fig. 4): Length 32 millimeters; width 33 millimeters; height 7 millimeters.

Description.—A very good description of this interesting Californian species was given as early as 1863 by Rémond. It was first figured by Gabb in 1869. The test is variable in size, ranging from about 1 to 3½ inches in diameter and from one-eighth to one-half inch in height. In marginal outline it varies considerably, being usually suboblong or subquadrate; sometimes

suboval or subovate; length usually equal to or greater than width, though sometimes considerably less, usually broadest back of the center but in front of the apical system. The upper surface is somewhat irregularly convex; much depressed though less so posteriorly than anteriorly, rising directly from the margin to the low apex which is more or less posteriorly excentric, sloping more steeply posteriorly than anteriorly. The margin is thin and is usually slightly notched in the middle of the posterior end. The under surface is flat or slightly concave.

The ambulacral areas are wide, widest at the margin, where they are wider than the interambulacral areas; dorsal portions petaloid. The petals are large, the total area covered by them being greater relatively than in most related forms; the anterior three longer than the posterior two, the odd petal equal to or slightly longer than the anterior pair; all of them except the odd petal approaching rather close to the margin. The anterior paired petals curve toward each other, so as to be less divergent than the posterior pair, which are very short, widely divergent, and have their anterior side the longer and their poriferous zones widely divergent. The poriferous zones are of moderate width, those of the odd petal usually being narrower than the rest; pores oval and conjugated. The interporiferous areas are wide, much wider than the poriferous zones.

The interambulacral areas are very narrow between the petals, wide at the margin. The surface of the test is covered with small uniform perforate tubercles which are slightly larger on the under surface.

The apical system is very excentric posteriorly, being situated from one-third to more than one-half the distance from the center to the posterior margin. The specimens which are larger and more elongate longitudinally are those with the most excentric apical system. The madreporite is large, subpentagonal, with four genital pores as the anterior points of the pentagon, the two anterior nearer together than the two posterior. There are also five very small radial plates each perforated by a minute pore.

The peristome is small, excentric posteriorly, though decidedly less so than the apical system. The ambulacral furrows are simple and straight for a short distance from the peristome, then fork nearly symmetrically into two strong furrows which diverge for a short distance, then converge slightly and continue nearly to the margin. In young specimens they diverge continuously to the margin. There do not appear to be many branches given off, though the specimens are rarely sufficiently well preserved to show this feature.

The periproct is very small, circular or subcircular, inframarginal, nearly marginal, usually 1 or 2 millimeters from the inner edge of the slight notch in the posterior border.

Related forms.—Dendraster gibbsii is most closely related to *D. excentricus*, but differs from the latter in having its apex less central, its apical system more excentric, its posterior petals less widely divergent and with less widely divergent poriferous zones, and its periproct usually somewhat nearer to the border. Some of the younger specimens of *D. gibbsii* also resemble *D. coalingaensis*, but can be separated from it by its more excentric apical system, its less symmetrically elliptical ambulacral petals, and its more divergent posterior petals. No foreign forms appear to be closely related to *D. gibbsii*. The Patagonian species *Scutella patagonensis* Desor [1] resembles *D. gibbsii* in occurrence in two quite different forms, one longitudinally elongate and one transversely elongate, which yet evidently belong to the same species, for they grade into one another and they occur together.

Localities.—Kern Lake, Buena Vista County (Rémond); near Buena Vista Lake, Kern County (Gabb, Merriam); near Santa Cruz (Ashley); 8 miles north of Coalinga (Pl. LXXXIX, figs. 1a, 1b); ridge south of Garcas County, Coalinga district (Pl. LXXXIX, figs. 2, 3); 10 to 12 miles southeast of northwest end of Kettleman Hills, Coalinga district (Pl. LXXXIX, fig. 4); numerous other localities in Coalinga district (including U. S. Geol. Survey localities Nos. 3849, 4751, 4753, 4755, 4757, 4767, 4768, and 4806); San Jacinto; Capitola (Pack); San Gregorio (Pack); Graciosa Ridge near Orcutt, Santa Maria district, California.

[1] See Reports of the Princeton University expeditions to Patagonia, 1896–1899, vol. 4, pt. 2, pp. 55–60; Pl. XI, figs. 4a, b, c, d, e.

Geologic horizon.—Jacalitos and Etchegoin formations, in Coalinga district, upper Miocene and lower Pliocene (?). Fernando formation in Santa Maria district, upper Miocene or lower Pliocene.

Collections.—U. S. National Museum (165547, A; 165611, B, C; 165704, D); University of California, California Academy of Sciences; Yale University.

Dendraster oregonensis (Clark).

Plate XC, figure 1.

Scutella (Echinarachnius) oregonensis Clark, 1909, in Dall, U. S. Geol. Survey Prof. Paper 59, p. 140, Pl. VII, fig. 2.

Determinative characters.—Test small; subcircular in marginal outline, broader posteriorly than anteriorly; the whole form greatly depressed, the upper surface moderately convex, rising directly from the rather thin margin to the low, anteriorly excentric apex; under surface flat. Apical system excentric posteriorly, about one-fourth the radius from the center. Ambulacral petals relatively large, approaching rather close to the margin; the two posterior shorter than the anterior three and with posterior poriferous zones straight or nearly so; open at their ends. Peristome circular, subcentral. Ambulacral furrows feeble. Periproct small, subcircular, supramarginal.

Dimensions.—Length 20 millimeters; width 20 millimeters; height 3 millimeters.

Description.—This recently described Pacific coast Dendraster is one of the smallest representatives of the genus, rarely exceeding an inch in diameter.

In marginal outline it is subcircular; though broader posteriorly than anteriorly. The whole form is greatly depressed, the upper surface being evenly rounded and rising directly from the rather thin margin to the low apex which is situated forward of the center. The under surface is flat or faintly concave.

The ambulacral areas are rather narrow; dorsal portions petaloid. The petals are relatively large, approaching rather close to the margin, the two posterior shorter than the anterior three, of which the odd petal is the longest. The petals are straight or nearly so, the anterior pair slightly more divergent than the posterior pair, and all are open at their ends. The poriferous zones are broad, pores oval, pairs of pores conjugated; the posterior zones of both pairs straight or nearly so. The interporiferous areas are narrow, about as wide or slightly wider than the poriferous zones.

The interambulacral areas are broad, about equally so between the petals. The surface of the test is closely set with small tubercles, apparently imperforate, set in deep scrobicules, the tubercles being slightly larger on the under surface.

The apical system is excentric posteriorly, being situated about one-fourth the distance from the center to the posterior border. The details could not be made out upon the specimens studied.

The peristome is small, circular, subcentral; the ambulacral furrows feeble, not showing very well upon the specimens; but apparently simple and straight for a short distance from the peristome, then forking symmetrically.

The periproct is small, subcircular, supramarginal, about 1 millimeter from the posterior ends.

Related forms.—*D. oregonensis* is closely allied to *D. interlineatus*, the superficial resemblance being very striking, but differs in having all the petals open at the ends and the posterior and anterior paired petals less symmetrically subelliptical in form by reason of the fact that the posterior poriferous zones are straight or nearly so. *D. oregonensis* also differs in being relatively higher in proportion to its width and has a relatively larger periproct. These differences are not very pronounced, and further collecting may result in the merging of the two species.

Localities.—Near Empire City and Fossil Point, Coos Bay, Oreg.

Geologic horizon.—Empire formation, upper Miocene.

Collection.—U. S. National Museum (153975).

Dendraster coalingaensis Twitchell, n. sp.

Plate XC, figures 2a–c.

Echinarachnius gibbsii Arnold, 1909, pars, U. S. Geol. Survey Bull. 396, pp. 34 pars, 42 pars, 162; Pl. XXVIII, figs. 4, 4a.

Echinarachnius gibbsii Arnold, 1910, pars, U. S. Geol. Survey Bull. 398, p. 338, Pl. V, figs. 4, 4a.

Determinative characters.—Test small; broadly ovate in marginal outline; broadest about opposite or to the rear of the apical system; upper surface convex, greatly depressed though less so posteriorly than anteriorly, arising directly from the thin margin to the apex which is excentric posteriorly and about coincident with the apical system; under surface concave around the peristome. Apical system excentric posteriorly, about one-fourth the radius from the center. Ambulacral petals wide, straight and symmetrically subellipical; the posterior pair shorter than the others, and usually less divergent than the anterior pair. Peristome small, slightly excentric posteriorly; ambulacral furrows simple and straight for about one-third the radius, then forking, each pair of branches diverging continuously nearly to the margin, where they split into several small branches. Periproct small, circular, inframarginal, almost marginal.

Dimensions.—Length 33 millimeters; width 31 millimeters; height 5 millimeters. One of the smallest specimens studied was only 14 millimeters in diameter.

Description.—This small Dendraster is found in association with *D. perrini* in the Coalinga district, California, whence the name given. A number of specimens were collected and one was figured by Arnold. The test is small, ranging from one-half to 1½ inches in diameter; broadly ovate in marginal outline, broadest opposite or slightly to the rear of the apical system. The upper surface is somewhat irregularly convex, greatly depressed, though less so posteriorly than anteriorly, rising directly from the margin to the low, posteriorly excentric apex. The margin is thin.

The ambulacral areas are wide, widest at the margin, where they exceed the interambulacral areas in width; dorsal portions petaloid. The petals are of medium length, wide, straight, and symmetrically subelliptical, wide open at the ends; the anterior three longer than the posterior two, the odd petal slightly longer than the anterior pair; the posterior pair usually less divergent, sometimes about as equally divergent as the anterior pair. The poriferous zones are wide, outer row of pores subelliptical, inner row subcircular; pairs of pores conjugated. The interporiferous areas are wide, and slightly tumid.

The interambulacral areas are narrow between the inner ends of the petals, wide from the outer ends of the petals to the margin, each area of about equal width with the others. The surface of the test is covered with small, uniform, perforate tubercles in deep scrobicules. The tubercles and scrobicules are slightly larger on the under surface and larger than in related forms.

The apical system is excentric posteriorly, being situated about one-fourth the distance from the center to the posterior border and coincident or very nearly coincident with the apex. There is a large pentagonal madreporite, four genital pores of which the anterior pair are nearer together than the posterior pair; and five small radial plates each perforated by a minute pore.

The peristome is small, subcircular, slightly excentric posteriorly, but slightly less so than the apical system. The ambulacral furrows are simple and straight for about one-third the way to the margin, then fork symmetrically, each pair of branches diverging continuously to near the margin where they split into several small branches.

The periproct is small, circular, inframarginal, almost marginal, usually less than a millimeter from the posterior edge.

Related forms.—*D. coalingaensis* is closely related to *D. excentricus*, of which it may be an ancestral form. It differs from the latter, however, in being much smaller and less tumid centrally, in having its apex less central and more nearly coincident with the apical system, and in having its periproct nearer to the margin. *D. coalingaensis* also closely resembles *D. gibbsii*, especially the young specimens of the latter species, but can be readily separated by its

much less excentric apical system, its more symmetrically elliptical ambulacral petals, and the fact that its posterior petals diverge less widely and also have poriferous zones which are less widely divergent at their ends and more equal in length. Some specimens of *D. arnoldi* resemble *D. coalingaensis;* but they have thicker margins, more widely open ambulacral petals, more conspicuous tubercles, more tumid interporiferous areas, and a central apex which is also not coincident with the apical system.

Localities.—Near A. Kreyenhagen's place (type), and 1,244-foot hill 4 miles southeast of northwest end of Kettleman Hills, in Coalinga district, California.

Geologic horizon.—Etchegoin formation (apparently limited to the upper portion of the formation), upper Miocene and lower Pliocene (?).

Collection.—U. S. National Museum (165537).

Dendraster sp. (Conrad).

Scutella sp. Conrad, 1857, U. S. Pacific R. R. Expl., vol. 7, Pl. X, figs. 3, 4; no description.
Dendraster sp. Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 704.

As Conrad gave no description of this form its exact relationships can not be determined with certainty. It resembles *Dendraster interlineatus* in some respects, but not closely enough to justify its identification with that species.

Echinarachnius sp. Conrad.

Echinarachnius sp. Conrad, 1857, U. S. Pacific R. R. Expl., vol. 7, Pl. IX, fig. 5; no description.

This is only a poor figure of an imperfect specimen, unaccompanied by a description. It is not entitled to recognition and the exact relationships can not be determined from such data.

Genus ASTRODAPSIS Conrad (amended).

Astrodapsis Conrad, 1869, Acad. Nat. Sci. Philadelphia Proc., vol. 8, p. 315.
Astrodapsis Conrad, 1857, U. S. Pacific R. R. Expl., vol. 7, Pal. Rept., p. 196.
Astrodapsis Rémond, 1863, California Acad. Nat. Sci. Proc., vol. 3, p. 52.

The writer does not agree with Duncan[1] in regarding Conrad's genus Astrodapsis as a synonym of Breynius's genus Arachnoides. The inframarginal position of the periproct, the depressed apical system, and the elevated ambulacral areas alternating with depressed interambulacral areas sufficiently distinguish Astrodapsis from Arachnoides.

Conrad's description of his genus is as follows: "Suboval; depressed; ambulacral areas elevated or ridged; ambulacra nearly straight, widely open at the extremity; mouth central; anus submarginal, beneath; radiating grooves as in Laganum." This description was good in view of the small amount of material Conrad had, but it now becomes necessary to redraw the diagnosis of the genus in order to make a few emendations.

Description.—Test depressed, subdiscoidal to broadly subconical in general form, circular to subelliptical in marginal outline, margin varying from thin to very thick, with or without notches opposite the ambulacral petals. Ambulacral areas elevated or ridged; interambulacral areas depressed. Ambulacral petals straight, extending nearly to the margin, widely open at the ends; poriferous zones nearly paralled, continuously diverging, or diverging, converging, and again diverging. Apical system more or less depressed. Peristome central or subcentral. Main ambulacral grooves simple and straight from peristome to margin, continuing as fainter grooves or processes over the margin and along the middle of the ambulacral ridges nearly to the apical system; two faint lines or processes are given off from the main grooves from one-half to two-thirds the way to the margin, which continue over the margin and along the upper surface between the tops of the ambulacral ridges and the bottoms of the ambulacral depressions nearly to the apical system. Periproct small, inframarginal, almost marginal.

[1] Duncan, P. M., Revision of genera and great groups of the Echinoidea: Linn. Soc. Lour. Zoology, vol. 23, p. 195, 1891.

Astrodapsis antiselli Conrad.

Plate XCIV, figures 3, 4a–b.

Astrodapsis antiselli Conrad, 1856, Acad. Nat. Sci. Philadelphia Proc., vol. 8, p. 315; no figures.
Astrodapsis antiselli Conrad, 1857, U. S. Pacific R. R. Expl., vol. 7, p. 196, Pl. X, figs. 1, 2.
Astrodapsis antiselli Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Astrodapsis antiselli Gabb, 1869, California Geol. Survey Rept., Paleontology, vol. 2, p. 110.
Astrodapsis antiselli Cooper, 1888, State Mineralogist California Seventh Rept., p. 270.
Astrodapsis antiselli Arnold, 1908, U. S. Nat. Mus. Proc., vol. 34, Pl. XXXV, fig. 10; no description.
Astrodapsis antiselli Arnold, 1909, U. S. Geol. Survey Geol. Atlas, Santa Cruz folio (No. 163), Pl. II, fig. 58.
non *Astrodapsis antiselli* var. *arnoldi* Pack, 1909, Univ. California Dept. Geology Bull., vol. 5, No. 18, pp. 279–281, Pl. XXIV, figs. 1, 2. See *Astrodapsis arnoldi*.
Astrodapsis antiselli Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 702.

Determinative characters.—Test medium in size; regularly oval in marginal outline, longer than broad, slightly truncated at anterior end, slightly pointed at posterior end, with faint notches opposite ends of petals; margin rounded and very thick, almost as thick as rest of test. The whole form is considerably depressed, almost equally so from edge to edge, and therefore subdiscoidal; the upper surface with broad, flattened ambulacral ridges alternating with narrow interambulacral depressions; apex excentric anteriorly, in front of depressed apical system; lower surface slightly concave. Ambulacral petals large, broad, tumid, especially near apical system; poriferous zones narrow, at first diverging, then converging slightly from one-fourth to one-third the way to the margin, and again diverging to the wide-open ends which are nearly at the margin. Peristome central; the main ambulacral grooves straight, well defined, and rather deep from peristome to margin and continuing as faint lines over margin to near apex, two faint lines are given off about halfway to margin, which continue over margin to near apical system. Periproct small, inframarginal, almost marginal.

Dimensions.—Specimen B: Length 57 millimeters; width 50 millimeters; height 14 millimeters.

Description.—This species was one of the first of the Tertiary echinoids to be reported from the Pacific coast of the United States, having been described by Conrad as early as 1856. Conrad founded his new genus Astrodapsis upon this species. The test is medium in size, averaging about 2 inches in length. In marginal outline it is regularly oval, longer than broad, usually slightly truncated at the anterior end and somewhat pointed at the posterior end, with very slight notches opposite the ends of the petals; margin rounded and very thick, almost equal in thickness to the rest of the test, somewhat thicker anteriorly than posteriorly. The whole form considerably depressed, subdiscoidal; the upper surface with broad flattened ambulacral ridges alternating with narrow interambulacral depressions; apex excentric anteriorly in front of apical system; under surface slightly concave.

The ambulacral areas are wide; dorsal portions petaloid. The petals are large, broad, tumid, widest and most tumid near the apical system, constituting broad ridges, all of them extending nearly to the margin, wide open at the ends; interporiferous areas very wide; poriferous zones narrow and of nearly equal breadth throughout their length, at first diverging, then converging slightly from one-fourth to one-third the way from the margin, and again diverging; inner row of pores round, outer row broadly slitlike, pairs of pores conjugated.

The interambulacral areas are narrow, decidedly depressed, forming radial grooves in the upper surface. The whole surface of the test is covered with small but conspicuous tubercles, which make the surface feel rough; they are larger and more conspicuous in the interporiferous areas.

The apical system is slightly excentric anteriorly, in a star-shaped depression below the level of the ambulacral ridges. There appear to be only four genital pores which are located at four of the points of the star-shaped depression. No further details could be made out.

The peristome is central, circular to subpentagonal. The main ambulacral grooves are straight, well defined and rather deep from peristome to margin and continue as faint lines over the margin and along the middle of the ambulacral ridges to the apical system; two faintly

defined processes are given off about halfway from the peristome to the margin, which extend to and over the margin and on the upper surface between the top of the ridges and the bottom of the depressions, becoming indistinct as the apical system is approached.

The periproct is small, subcircular, inframarginal, almost marginal.

Related forms.—Duncan[1] regarded Conrad's genus Astrodapsis as a synonym of Breynius's genus Arachnoides; but, though there are certain points of resemblance, the inframarginal position of the periproct, the more or less depressed apical system and the elevated, ridgelike ambulacral areas alternating with depressed groovelike interambulacral areas on the upper surface would appear to sufficiently differentiate the genus Astrodapsis.

The present species is readily separated from the other representatives of the genus, although some confusion has arisen in the literature and in various collections because of the obscure location of Conrad's description and figures. *A. whitneyi* differs in being broadly subconical and in having a thin margin, more circular outline, more pronounced marginal notches, higher ambulacral ridges and deeper interambulacral depressions. *A. tumidus* differs in being smaller and in having a greater difference between the height of the ambulacral ridges and interambulacral depressions.

Localities.—Monterey County (type), and 2 miles south of San Lucas, Monterey County (specimen B), Cal. Conrad also cites Estrella, and Gabb gives near Buena Vista Lake, both in California.

Geologic horizon.—Santa Margarita formation, middle or upper Miocene.

Collection.—U. S. National Museum (165466, A; 165466a, B). (Both the type and the specimens collected by Arnold, which include specimens A and B.)

Astrodapsis arnoldi Twitchell, n. sp.

Plate XCV, figure 1.

Astrodapsis whitneyi Arnold, 1909, U. S. Geol. Survey Bull. No. 396, p. 63, Pl. XI, fig. 1.
Astrodapsis antiselli var. arnoldi Pack, 1909, California Univ. Dept. Geology Bull., vol. 5, No. 18, pp. 279–281, Pl. XXIV, figs. 1, 2.
Astrodapsis whitneyi Stefanini, 1911, pars, Soc. geol. italiana Boll., vol. 30, p. 703.

Determinative characters.—Test large, larger than most representatives of the genus; circular in marginal outline; margin and wide submarginal area notably thin, undulating, with pronounced posterior notches and less pronounced anterior notches. The whole form considerably depressed, greatly and nearly equally so for half the distance from margin toward the center, moderately elevated centrally, with rather broad and somewhat flattened ambulacral ridges alternating with broad deep interambulacral depressions. The inner ends of the ambulacral ridges almost coalesce around the slightly depressed apical system and form the somewhat flattened subcentral apex of the test. Lower surface flat or nearly so. Petals moderately wide, elongate subelliptical, nearly reaching the margin where wide open; inner halves elevated and tumid, outer halves depressed and merging with submarginal area; inner rows of pores of each petal nearly parallel for most of their length. Peristome small, circular, central; main ambulacral grooves simple, straight and deep to the margin, continuing as faint lines straight and deep over margin and along middle of ambulacral ridges nearly to apex; two faint processes are given off about half way to margin which continue over margin and on upper surface to near the apex. Periproct very small, inframarginal, almost marginal.

Dimensions.—Length 76 millimeters; width 75 millimeters; height 10 millimeters.

Description.—The test of this new Astrodapsis is unusually large. In marginal outline it is circular; the margin is markedly thin, undulating, with well-defined notches opposite the ends of the petals, the posterior notches being slightly larger than the anterior pair, which are larger than the odd one; the submarginal area for nearly half the way toward the center is also thin, about as thin as at the margin. Centrally, within the area circumscribed by the thin and flattened submarginal area, the upper surface is moderately elevated with rather broad and

[1] Duncan, P. M., Revision of genera and great groups of the Echinoidea: Linn. Soc. Jour. Zoology, vol. 23, p. 165, 1891.

somewhat flattened ambulacral ridges alternating with broad deep interambulacral depressions, the central elevation being flattened on top around the slightly depressed apical system. The ambulacral ridges almost coalesce around the apical system. The apex is central or subcentral; the lower surface flat or but very slightly concave from margin to center.

The ambulacral areas are wide, slightly wider at the margin than the interambulacral areas, narrowing rapidly to a point about midway between the margin and the center of the test, where narrower than the interambulacral areas; dorsal portions petaloid. The petals are of moderate width, elongate subelliptical, long, nearly reaching the margin, the inner half of each petal elevated, tumid but somewhat flattened on top, the outer half depressed, gradually broadening and merging with the flattened submarginal area; the poriferous zones are narrow, the inner rows of pores nearly straight and parallel for most of their length, wide apart at the ends, composed of large, round openings; outer rows diverging for about half the distance to the margin then drawing near inner rows, pores slitlike; pairs of pores conjugated. The surface of the odd petal is slightly higher than that of the anterior pair, which is slightly higher than that of the posterior pair.

The interambulacral areas at the margin are somewhat narrower than the ambulacral areas, near the apex they are much narrower, almost obliterated; they become depressed rather rapidly from near the apex to about halfway to the margin, whence they merge with the flattened submarginal area, though keeping slightly more depressed than the adjacent ambulacral areas. The surface of the test is covered with small but rather conspicuous tubercles, most conspicuous in the interporiferous areas.

The apical system is central, slightly depressed below the top of the ambulacral ridges. The details could not be made out on the specimen studied.

The peristome is small, circular, central. The main ambulacral grooves are simple, straight, and deep from peristome to margin; they continue as faint lines over the margin, and along the middle of the ambulacral ridges nearly to the apex; two faintly defined processes are given off about halfway from peristome to margin which extend to and over the margin and along the upper surface between the top of the ridges and the bottom of the depressions, near the suture line between the ambulacral and interambulacral plates, disappearing near the inner ends of the interambulacral depressions.

The periproct is very small, inframarginal, almost marginal.

Related forms.—*A. arnoldi* is most closely related to *A. whitneyi*. In fact specimens of each species answer to Rémond's description, and in view of the loss of Rémond's type it is not possible to be sure which form was really his. Merriam, evidently influenced by Gabb's figure, and before Arnold's and Pack's specimens were discovered, redescribed and figured as *A. whitneyi* the broadly subconical form. Arnold's specimen, with the arch of the upper surface commencing some distance in from the edge, was identified by him as an *Astrodapsis whitneyi*. Pack describes and figures a specimen which is evidently identical with that of Arnold just referred to but errs in treating it as a variety of *A. antiselli*, from which it differs considerably, in fact, much more than it does from the *A. whitneyi* of Gabb and Merriam. The present form, represented by the specimens of Arnold and of Pack, appears to be entitled to recognition as a distinct species, and as the writer agrees with Merriam in regarding the broadly subconical form figured by Gabb as most probably Rémond's *A. whitneyi* the present species is named after Arnold, who collected the type in the Coalinga district, California. *A. arnoldi* is readily distinguished from *A. whitneyi* in having the arch of the upper surface commencing almost halfway in from the edge, the margin and wide submarginal area being notably thin, also in having the outer portions of the petals greatly depressed and merging with the submarginal area, and the ambulacral ridges somewhat broader and more flattened near the apex. *A. antiselli* has a much thicker margin and is subdiscoidal in form besides differing in other ways. *A. jacalitosensis* has its apical region much more depressed, and into this depression extend the interambulacral depressions; the odd petal is higher and more conspicuous and the inner lines of pores of the petals diverge instead of being nearly parallel.

Localities.—Above Big Blue, west of Peerless Oil property, 9 miles north of Coalinga (type), and Salinas Valley, Monterey County, Cal.

Geologic horizon.—Santa Margarita formation, middle or upper Miocene.

Collections.—U. S. National Museum (165594); University of California.

Astrodapsis whitneyi Rémond.

Plate XCV, figures 2a–c.

Astrodapsis whitneyi Rémond, 1863, California Acad. Nat. Sci. Proc., vol. 3, p. 52; no figure.
Astrodapsis whitneyi Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Astrodapsis whitneyi Gabb, 1869, California Geol. Survey Rept., Paleontology, vol. 2, pp. 37, 110, Pl. XIII, figs. 67, 67a.
Astrodapsis whitneyi Cooper, 1888, State Mineralogist of California Seventh Rept., p. 271.
Astrodapsis whitneyi Merriam, 1899, California Acad. Sci. Proc., 3d ser., Geology, vol. 1, No. 5, p. 167, Pl. XXI, figs. 4, 4a.
non *Astrodapsis whitneyi* Arnold, 1909, U. S. Geol. Survey Bull. 396, p. 63, Pl. XI, fig. 1. See *Astrodapsis arnoldi*.
Astrodapsis whitneyi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 703.

Determinative characters.—Test medium to large; circular in marginal outline, broadly subconical in general form; margin thin, with small subequal ambulacral notches. Upper surface rising directly from margin to the relatively high, slightly anteriorly excentric apex; with high, narrow, steep-sided ambulacral ridges alternating with broad, deep interambulacral depressions. Lower surface concave. Petals relatively narrow, elongate subelliptical, nearly reaching margin, wide open at ends; inner rows of pores nearly parallel for most of their length. Apical system slightly excentric anteriorly, faintly depressed below top of petals. Peristome central; main ambulacral grooves simple, straight, and deep to the margin, continuing as faint lines on upper surface nearly to apex; two faint processes given off about halfway to margin, which also continue to and over margin and on upper surface nearly to apex. Periproct small, subcircular, inframarginal, almost marginal.

Dimensions.—Length 50 millimeters; width 50 millimeters; height 13 millimeters.

Description.—This species was one of the first fossil echinoids to be reported from the California Tertiary deposits, having been described, but not figured, by Rémond in 1863. The test is medium to large, ranging, according to Merriam, up to 65 millimeters in diameter. In marginal outline it is circular; margin thin, with small but well-defined, subequal notches opposite all the ambulacral petals. The whole form is depressed, but less so than in related species, the upper surface being broadly subconical, rising directly from the margin to the relatively high, slightly anteriorly excentric apex; with high, narrow, steep-sided ambulacral ridges alternating with broad, deep, interambulacral depressions. The under surface is concave, the concavity gradually deepening to the peristome, where it is about one-third of the height of the test.

The ambulacral areas are wide, wider than the interambulacral areas; dorsal portions petaloid. The petals are relatively narrow, elongate subelliptical, long, nearly reaching the margin; the poriferous zones are narrow, about half as wide as the tumid interporiferous areas, the inner rows of pores elevated, nearly straight, and parallel for most of their length, wide apart at the ends, composed of large, round openings; outer rows depressed, diverging for about half the distance to the margin, then drawing near the inner rows, pores slitlike; pairs of pores conjugated; several pairs of pores occur beyond and diverge from the ends of the petals.

The interambulacral areas at the margin are somewhat narrower than the ambulacral areas; near the apex they are much narrower, almost obliterated; they are gradually depressed from near the apex to the margin. The surface of the test is covered with small, inconspicuous tubercles, varying in size and set in shallow scrobicules; the tubercles are somewhat larger in the interporiferous areas than elsewhere.

The apical system is slightly excentric anteriorly, faintly depressed below the tops of the ambulacral petals. The details could not be made out on the specimen.

The peristome is central. The main ambulacral grooves are simple, straight, and deep from peristome to margin; they continue as fainter lines over the margin and along the middle

of the ambulacral ridges nearly to the apex; two faintly defined processes are given off about halfway from peristome to margin, which extend to and over the margin and on the upper surface between the tops of the ridges and bottom of the depressions.

The periproct is very small, subcircular, inframarginal, almost marginal.

Related forms.—As the location of the type is unknown, some doubt exists as to the exact form which should be called *A. whitneyi*. The species described under the name of *A. arnoldi* (p. 199) agrees with Rémond's description of *A. whitneyi* as well as if not slightly better than that described and figured by Merriam as *A. whitneyi*, which is here adopted. However, Gabb figured as *A. whitneyi* a specimen similar to the present form, and the writer here follows Merriam in regarding it as probably similar to Rémond's original form. *A. whitneyi* is most closely related to *A. arnoldi*, which differs in having the arch of the upper surface commence nearly halfway in from the margin to the center, in having a markedly thin margin and submarginal area, and the outer half of each petal greatly depressed and merging with the submarginal area. *A. whitneyi* is also closely related to *A. jacalitosensis*, which differs in much the same way as *A. arnoldi*, and further in having a more deeply depressed apical system, the interambulacral depressions extending to and joining the apical depression, and the inner line of pores of the petals diverging. *A. whitneyi* is also allied to *A. tumidus*, which is smaller, has a thicker margin, and a less definitely broadly, subconical upper surface.

Localities.—Kirkers Pass, north of Mount Diablo, and south shore of San Pablo Bay, Cal.

Geologic horizon.—San Pablo formation (upper part), upper Miocene.

Collection.—University of California (19426).

Astrodapsis tumidus Rémond.

Plate XCV, figures 3a–b; Plate CVIII, *A*.

Astrodapsis tumidus Rémond, 1863, California Acad. Nat. Sci. Proc., vol. 3, pp. 52, 53; no figure.
Astrodapsis tumidus Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Astrodapsis tumidus Gabb, 1869, California Geol. Survey Rept., Paleontology, vol. 2, pp. 37, 110, Pl. XIII, figs. 68, 68a.
Astrodapsis tumidus Cooper, 1888, State Mineralogist of California Seventh Rept., p. 270.
Astrodapsis tumidus Merriam, 1899, California Acad. Sci. Proc., 3d ser., vol. 1, No. 5, p. 166, Pl. XXI, fig. 3.
Astrodapsis tumidus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 703.

Determinative characters.—Test small, circular to oval in marginal outline; margin thick, especially opposite petals, faintly notched opposite petals. Whole form greatly depressed; upper surface slightly and more or less regularly convex from edge to edge, with high, moderately wide ambulacral ridges alternating with rather narrow interambulacral depressions. The ridges are conspicuous for two-thirds the way from center to margin, then become nearly flush with the adjacent surfaces; the depressions extend down the middle of the interambulacral areas from apex to margin, widening between the petals. Apex low, subcentral; under surface slightly concave. Petals wide in proportion to length, subelliptical, nearly reaching the margin; poriferous zones about one-third width of tumid interporiferous areas, inner row of pores elevated, outer row depressed. Apical system subcentral, slightly depressed below tops of petals. Peristome small, circular, subcentral; main ambulacral grooves simple, straight, and deep to margin, continuing over margin and nearly to apex as a faint line. Periproct very small, circular, inframarginal, almost marginal.

Dimensions.—Length 30 millimeters; width 30 millimeters; height 8 millimeters.

Description.—This species is one of the earliest reported Pacific coast fossil echinoids, having been described, but not figured, by Rémond in 1863. The test is small, rarely exceeding 1½ inches in diameter. In marginal outline it is somewhat variable, though usually oval or circular; margin moderately thick and rounded, quite thick opposite the ends of the petals, where equal to more than half the height of the test, with faint notches opposite the ends of the petals. The whole form is greatly depressed; the upper surface slightly and more or less regularly convex from edge to edge, with high, moderately wide ambulacral ridges, which are conspicuous for two-thirds of the way from the center, alternating with rather narrow, deep, interambulacral depressions. The apex is low, subcentral; under surface slightly concave.

The ambulacral petals are relatively wide in proportion to their length, subelliptical, nearly reaching the margin, wide open at the ends, inner two-thirds or more tumid and prominent, outer ends nearly flush with the adjacent surfaces; poriferous zones narrow, about one-third the width of the interporiferous areas; the inner row of pores elevated, pores round, outer row depressed, pores slitlike, pairs of pores conjugated.

The interambulacral areas are deeply depressed along the middle from apex to margin. The surface of the test, including the margin and interporiferous areas is covered with small, conspicuous tubercles in deep scrobicules.

The apical system is subcentral, slightly but distinctly depressed below the tops of the petals. The details could not be made out on the specimen.

The peristome is small, circular, subcentral. The main ambulacral grooves are simple, straight, and deep from peristome to margin, continuing as faint lines over the margin and along the ambulacral ridges nearly to the apex. The two faint processes usually given off from the main grooves on species of this genus could not be clearly made out on the specimen studied.

The periproct is very small, circular, inframarginal, almost marginal.

Related forms.—*A. tumidus* is most closely related to *A. whitneyi*, but has a thicker margin, especially opposite the ends of the petals, is, in general, smaller, lower, and not subconical, has only faint marginal notches, petals which are broader in proportion to their length, a more depressed apical system and a less concave lower surface. *A. tumidus* presents some features similar to *A. antiselli*, which make descriptions sound alike; but the forms are quite distinct, *A. tumidus* being readily distinguished by its smaller size, less thickness, much narrower and higher ambulacral ridges, and wider interambulacral depressions.

Localities.—Kirkers Pass and 2 miles west of Walnut Creek House (Rémond); San Pablo Bay, Cal. (Merriam).

Geologic horizon.—San Pablo formation (middle part), upper Miocene.

Collection.—University of California (19424).

Astrodapsis jacalitosensis Arnold.

Plate XCV, figure 4.

Astrodapsis jacalitosensis Arnold, 1909, U. S. Geol. Survey Bull. 396, pp. 63–64, Pl. XV, fig. 5.
Astrodapsis jacalitosensis Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 703.

Determinative characters.—Test large; broadly subovate in marginal outline, broadest posteriorly; margin thin, deeply notched opposite the posterior petals. The whole form considerably depressed, greatly and equally so for half the way in from edge; centrally the upper surface is higher, with conspicuous ambulacral ridges, of which the odd anterior one is the highest, thus forming the anteriorly excentric apex of the test, and pronounced interambulacral depressions which merge with the deep depression in the apical region, the posterior depression being deeper and narrower than the rest. Petals tumid and elevated proximally, depressed distally; inner rows of pores diverging in nearly straight lines to near the margin, where wide apart outer row curving at first away from and then toward the inner row. Apical system excentric anteriorly, deeply depressed. Details of lower surface could not be made out. Periproct small, inframarginal, almost marginal.

Dimensions.—Length 77 millimeters; width 74 millimeters; height 15 millimeters.

Description.—This new Astrodapsis, which Arnold regards as a characteristic fossil of the Jacalitos formation in California, is large in size, being one of the largest representatives of the genus. In marginal outline it is broadly subovate, broadest posteriorly, slightly longer than wide, with deep notches opposite the posterior petals and faint notches opposite the other petals; margin thin. The whole form is considerably depressed, the marginal and submarginal areas greatly so and about evenly so all around. Within the inner portion of the petaloidal region there are alternating ambulacral ridges and interambulacral depressions. The depressions extend to and merge with the deep depression in the apical region, the posterior depression

being deeper, narrower, and more pronounced than the rest. The ridges are all conspicuous, but the odd anterior one is the highest and most pronounced, constituting the anteriorly excentric apex of the test. The details of the under surface could not be made out on the specimen.

The ambulacral areas are wide, slightly wider than the interambulacral areas at the margin; dorsal portions subpetaloid. The inner parts of the peatals are tumid and elevated, the outer parts depressed. The inner rows of pores gradually and continuously diverge to about one-fourth inch from the margin. The outer rows first diverge and then converge around the tumid parts of the petals and approach near to the inner row, beyond which point both rows diverge slightly to the margin. The inner rows of pores are large and round, the outer rows oval. There are one or two extra rows of pores within the main inner row. The pairs of pores are conjugated.

The apical system is excentric anteriorly, decidedly depressed below the surface of the petals. The details could not be made out.

The under surface not being exposed the details in regard to the peristome and ambulacral grooves can not be given. The periproct is small, inframarginal, almost marginal.

Related forms.—*A. jacalitosensis* is most closely related to *A. arnoldi*, which differs in having a less depressed apical region and not having the interambulacral depressions continuing to and joining the apical depression; also in having the inner rows of pores of each petal nearly parallel.

Locality.—South of Garza Creek, a mile southeast of Clark's place, Coalinga district, Cal.

Geologic horizon.—Jacalitos formation, upper Miocene.

Collection.—U. S. National Museum (165610).

Genus MELLITA Agassiz.

Mellita caroliniana Ravenel.

Plate XCI, figures 1a–b; Plate XCII, figures 1a–b.

Scutella caroliniana Ravenel, 1841, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 8, pp. 333, 334, text figure.
non *Mellita hexapora* L. Agassiz, 1841, Mon. échinodermes vivans et fossiles; Des scutelles, p. 41, Pl. IV, figs. 11, 12.
Mellita caroliniana Ravenel, 1848, Echinidæ, recent and fossil, of South Carolina, p. 160.
Scutella carolinensis Tuomey, 1848, Geology South Carolina Rept., p. 208.
Mellita caroliniana Ravenel, 1850, Am. Assoc. Adv. Sci. Proc., vol. 3, p. 160.
Mellita caroliniana Tuomey and Holmes, 1855, Pliocene fossils South Carolina, pp. 3, 4, Pl. I, fig. 4.
non *Mellita hexapora* Desor, 1858, Synopsis des échinides fossiles, p. 237.
Mellita caroliniata Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Mellita caroliniana Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 74.
Mortonia (Periarchus) carolinensis Conrad, 1866, Smithsonian Misc. Coll., vol. 7 (200), p. 21.
non *Mellita sexforis*, A. Agassiz, 1872, Revision of the Echini, pp. 141, 320.
non *Mellita sexforis* Gregory, 1891, Geol. Soc. America Bull., vol. 3, p. 107.
Scutella caroliniana Boyle, 1893, U. S. Geol. Survey Bull. 102, p. 262.
Periarchus carolinensis ? Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 699.
Mellita caroliniana Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 708.

Determinative characters.—Test small to very large; subcircular to subpentagonal in marginal outline, broadest between the anterior and posterior pairs of petals; six lunules, the odd posterior one much longer than the posterior pair which are longer than the rest; margin thin; the whole form greatly depressed, the upper surface rising gradually and but slightly from the margin to the very low, subcentral or posteriorly excentric apex; under surface flat. Ambulacral petals large, the posterior pair longer than the others. Apical system excentric anteriorly. Peristome small, subcircular, excentric anteriorly; ambulacral furrows simple and straight near the peristome, then forking, each pair of branches diverging and again converging near the margin. Periproct very small, elliptical, between the inner end of the odd posterior lunule and the peristome.

Dimensions.—The large form figured gave: Length 159 millimeters; width 152 millimeters; height about 10 millimeters.

Description.—This beautiful Mellita, first reported and described by Ravenel in 1841, is probably the oldest representative of the genus, as it undoubtedly existed in America in Miocene time. Hitherto the genus has not been positively known to have existed prior to the Pliocene. The species is rather rare, only a few specimens having been reported up to the present time. The test is small to very large in size, ranging from 1 to 6 inches in diameter. In marginal outline it is somewhat variable, being either subcircular, subpentagonal, or broadly subovate. It is usually about as long as broad; broadest between the anterior and posterior pair of petals, usually about the middle, but sometimes back of the middle of the test; rounded or truncated posteriorly. There are six lunules, one opposite each petal and very near the margin and one in the middle of the posterior ambulacrum, distant from the margin. The three anterior lunules are short and either pyriform or narrowly oblong, the posterior pair longer and usually narrowly oblong, and the odd posterior one much longer and frequently wider than all of the others, and either narrowly oblong or elongate subpyriform or elongate subelliptical. In young specimens the odd posterior lunule is much longer and more conspicuous relatively than in older ones. The whole form is greatly depressed, the upper surface rising gradually from the margin to the very low apex which is either central, slightly excentric anteriorly or excentric posteriorly, and rarely rises to a height of half an inch in even the largest specimens. The margin is thin, sometimes with faint notches opposite the posterior paired petals. The under surface is flat, or nearly so.

The ambulacral areas are relatively narrow in the petaloid dorsal portions, wide between the ends of the petals and the margin where they are wider than the interambulacral areas, narrowing again at the margin. The petals are large, and somewhat variable, extending halfway or decidedly more or less than halfway to the margin; subelliptical to subspatulate in form; usually narrower than those of *Mellita pentapora;* the posterior pair longer than the others, which are subequal in length. The poriferous zones are broad, equal to or broader than the interporiferous areas; pores oval, pairs of pores conjugated by very narrow, flexuous grooves.

The interambulacral areas are broad, broadest at the margin, where they are wider than the ambulacral areas. The surface of the test is closely set with very small, imperforate tubercles, set in deep scrobicules. The tubercles are larger on the under surface except along and near the ambulacral furrows.

The apical system is excentric anteriorly, large and stellate; four genital pores at the tips of the points of the star, the two posterior farthest apart; five small pores at the inner ends of the reentrant angles of the star.

The peristome is small, subcircular, excentric anteriorly; the ambulacral furrows simple and straight near the peristome, then forking, each pair of branches diverging and again converging near the margin so as to surround the lunules.

The periproct is very small, elliptical, between the inner end of the odd posterior lunule and the peristome.

Related forms.—*M. caroliniana* is closely related to *M. pentapora*, which is readily separated by its having only five lunules, by the greater height and more anterior position of its apex, and by having its lunules subequal in length and farther from the margin. *M. caroliniana* is still more closely related to the recent species *M. sexforis* A. Agassiz, which, however, differs in having its five ambulacral lunules all of the same length and its odd posterior lunule a little shorter than the others; another difference is that the distance between the pairs of food grooves in *M. sexforis* is greater than it is in *M. caroliniana*.

Localities.—Ravenel's type came from The Grove, Cooper River, 17 miles from Charleston, S. C. The large form figured in this paper came from South Carolina; but the exact locality is not known. Other localities are Goose Creek, Cooper River, and Bostick Landing, Great Peedee River, S. C.; Wilmington, and 3 miles north of Grifton, Pitt County, N. C.; Yorktown, Va.

Geologic horizon.—Duplin marl in South Carolina, and Yorktown formation, in North Carolina and Virginia, both upper Miocene.

Collections.—Academy of Natural Sciences of Philadelphia (1083); American Museum of Natural History; U. S. National Museum.

Genus SCUTASTER Pack.

Scutaster Pack, 1909, California Univ. Dept. Geology Bull., vol. 5, No. 18, p. 278, Pl. XXIII, fig. 2.

Description.—Test circular depressed, ambulacral star small. Lunules in the prolongation of the petals of the trivium, and either lacking in the bivium and posterior interambulacral space or not placed in the same relative positions as on the anterior portion of the test (Pack).

This genus was founded on a single imperfect specimen found in the Miocene deposits of California, which is also the type of the following species. Judging from the single figure which Pack gives, there are good grounds for believing that the new genus should be recognized.[1]

SCUTASTER ANDERSONI Pack.

Plate XCIII, figure 1.

Scutaster andersoni Pack, 1909, California Univ. Dept. Geology Bull., vol. 5, No. 18, pp. 278–279, Pl. XXIII, fig. 2.
Scutaster andersoni Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 704.

Description.—Only a single imperfect specimen of this species is known to exist,[1] and as the writer has had no opportunity of studying it, the description of Pack is given verbatim:

Test subcircular in outline, edges markedly thin. Upper surface regularly arched from the margin; apex anterior to the center. Apical system small and apparently central. Ambulacral star small; petals extending slightly less than halfway to the margin of the test, closed at the ends. Lateral petals broader than the posterior ones, but of almost the same length. Poriferous zones broad, and continuing full width almost to the ends of the petals. In the posterior petals the interporiferous area forms about one-third the width of the petal. Poriferous zones of the lateral petals equal in width to those of the posterior petals, but inclosed area broader. In the extension of the three anterior petals are broad lunules, over half as long as the petals; shallow grooves extend from the lunules to the margin. Anterior lunule slightly farther from the apical system than are the lateral ones. From the ends of the posterior petals the plates enlarge and the area broadens rapidly. No lunules were seen here, nor in the posterior interambulacral space. They may be represented by marginal notches, as the posterior edge of the specimen is lacking.

Dimensions.—Transverse diameter 44 millimeters; height 8 millimeters.
Locality.—East of Muir, Contra Costa County, Cal.
Geologic horizon.—Miocene.
Collection.—University of California.

Genus ENCOPE L. Agassiz.

ENCOPE MACROPHORA Ravenel.

Plate XCIII, figures 2a–e; Plate XCIV, figures 1a–f, 2.

Scutella macrophora Ravenel, 1842, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 8, pt. 2, pp. 334, 335, text figure.
Encope macrophora Ravenel, 1848, Echinidæ, recent and fossil, of South Carolina, p. 2.
Scutella macrophora Tuomey, 1848, Geology South Carolina Rept., p. 208.
Encope macrophora Ravenel, 1850, Am. Assoc. Adv. Sci. Proc., vol. 3, p. 160.
Encope macrophora Tuomey and Holmes, 1855, Pliocene fossils of South Carolina, pp. 2, 3, Pl. I, fig. 3.
Non *Scutella hexapora* Desor, 1858, Synopsis des échinides, p. 237. Desor evidently meant to give *S. caroliniana* Ravenel as a synonym of *S. hexapora* but gave *S. macrophora* instead.
Encope macrophora Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Ravenellia macrophora Lütken, 1863, Bid. til Kunds. om Echinoderme; Vidensk. Medd. Kjøbenhavn.
Macrophora macrophora Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 74.
Macrophora raveneli Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., p. 74.
Ravenellia macrophora Agassiz, 1883, Mus. Comp. Zoology Mem., vol. 10, No. 1, p. 89.
Scutella macrophora Boyle, 1893, U. S. Geol. Survey Bull. 102, p. 263.
Encope macrophora Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 708.

[1] Since the above descriptions were written Pack has published some new information regarding this unique Californian form, based on material recently discovered (California Univ. Dept. Geology Bull., vol. 7, No. 13, pp. 300–302, Pl. XV, figs. 2a–b, 1913). The new data establish the genus Scutaster on a firm basis. It is characterized by having but three lunules, which are situated in the anterior ambulacral areas. The new specimens show that *Scutaster andersoni* is transversely suboval in marginal outline, with narrow notches opposite the three anterior petals and broad shallow notches opposite the posterior pair. The apex is anteriorly and the apical system posteriorly excentric. Longitudinal diameter 53 millimeters; transverse diameter 62 millimeters; height 5 to 6 millimeters. The new locality is on the north slope of the San Emigdio Mountains, at the southern end of the San Joaquin Valley, where the tests are said to occur in great abundance. In regard to geologic horizon Pack says, "known only in the lower half of the Miocene."

Determinative characters.—Test small to large in size, suboval to subovate in marginal outline; truncated or convex posteriorly; shallow notches opposite the anterior petals, deep ones opposite the posterior pair; one large lunule in the posterior interambulacrum; margin thick; much depressed, being low and nearly flat along the front and sides, but rising toward the center and posteriorly in a low longitudinally elongate mound. Apex slightly excentric posteriorly, under surface flat. Ambulacral petals large, the posterior pair longer than the rest and curved around the lunule. Apical system excentric anteriorly. Peristome small, subcircular, excentric anteriorly; ambulacral furrows simple and straight for a short distance from the peristome, then forking. Periproct very small, subelliptical, at the edge of the lunule nearest the peristome.

Dimensions.—Specimen A: Length 97 millimeters; width 79 millimeters; height 18 millimeters. Specimen B: Length 62 millimeters; width 58 millimeters; height 11 millimeters. Specimen C: Length 31 millimeters; width 28 millimeters; height 5 millimeters.

Description.—This handsome species, the only representative of the genus Encope yet reported from the Cenozoic deposits of the Atlantic coast, was described by Ravenel as early as 1842. At first he placed it in the genus Scutella, but a few years later assigned it to the genus Encope. Both Lütken and Conrad founded new genera upon this species, but there appears to be no good ground for the recognition of either. Conrad's new species, *Macrophora ravenelli*, is believed to have been merely a young specimen of Ravenel's species. This species is rather abundant in a few localities in South Carolina and Florida, but is rare elsewhere. The test is variable in size, ranging from less than an inch to nearly 4 inches in longitudinal diameter. In marginal outline it is either suboval, somewhat ovate or obovate, or subquadrate; usually broader near the posterior end than near the anterior end; posterior border usually truncated, sometimes convex; a shallow notch opposite the odd petal, slightly deeper rounded ones opposite the anterior paired petals, and large deep angular ones opposite the posterior petals; the posterior notches vary from a flaring and subrectangular form in small specimens to a less open and more acute form, or one with parallel sides in larger specimens. A large lunule occupies the larger part of the posterior interambulacrum, which varies in form from circular in very small specimens to oval, subovate, or subspatulate in larger ones, the elongation being longitudinal when occurring; the width of the lunule is usually greater near the under surface, especially in large specimens. The whole form, including the margin, is thick, particularly so in large individuals. The whole test is much depressed, being nearly flat along the front and sides; but rising toward the center in a low longitudinally elongate mound which extends from about the middle of the odd petal to the posterior border. The height of the mound varies directly with the size of the specimen, ranging from less than an eighth to more than three-fourths of an inch. The apex is central or subcentral, being usually slightly excentric anteriorly, though sometimes slightly excentric posteriorly at the summit of the central mound, which is usually the anterior end of the raised and thickened margin of the lunule. The depressed marginal area is more or less distinctly corrugated by alternating low ridges and shallow troughs, there being two or three troughs between the notches in the margin. The under surface is flat or slightly concave, usually increasingly concave near the margin of the lunule.

The ambulacral areas are narrow in the petaloid region, wide in the marginal region where they about equal the interambulacral areas. The dorsal portions are petaloid. The petals are large, unequal in length, divisible into a bivium and a trivium; those of the trivium usually subequal in length, sometimes with the odd petal shorter than the other two, subelliptical or somewhat spatulate in form; those of the bivium much longer than the others, tapering gradually from the distal ends toward the apical system, gracefully curved around the lunule, all the petals open at the ends and extending about two-thirds the way to the margin. The poriferous zones are wide, as wide as or slightly wider than the interporiferous areas; the inner rows of pores nearly parallel and composed of rather large oval pores, outer row of smaller oval or elliptical pores at the bottom of deepened portions of very narrow grooves by which the pairs of pores are conjugated.

The interambulacral areas, except the posterior area, are narrow in the petaloid region, wider in the marginal region; the posterior interambulacral area is wider and its plates differ considerably in form from those of the other areas, because of the presence of the lunule. The whole surface of the test is covered with small uniform tubercles which are larger on the undersurface and inside the lunule.

The apical system is excentric anteriorly, in front of and below the apex on the more or less steeply sloping anterior side of the central mound. The madreporite is large, stellate or subpentagonal, nearly flush with the surface. There are five genital pores a short distance away from the points of the madreporic star, their relative positions varying somewhat, and five small radial plates each perforated by a small pore, on the proximal side of which there is a very small swelling. The posterior genital pore is sometimes somewhat displaced from the median line.

The peristome is small, subcircular to subpentagonal, excentric anteriorly; the ambulacral furrows rather deep, simple and straight for a short distance from the peristome, then forking, each pair of branches diverging somewhat, the three anterior pairs more so than the posterior two, extending to the margin and ending close alongside of the marginal notches. Each branch gives off one side branch on the outside at nearly right angles about halfway from the peristome to the margin, which soon bend and proceed to the margin. A very thin ridge extends out from the peristome along the middle of the short unbranched portion of each ambulacral furrow.

The periproct is very small, much smaller than the peristome, usually elliptical or subelliptical, sometimes subcircular or subpyriform, situated usually on the sloping edge of the lunule nearest the peristome, sometimes on the inner wall of the lunule, but near the under surface of the test.

This species presents variable features which illustrate in an interesting way changes due to the development of the individual. As the forms increase in size and age the lunule enlarges and becomes more elongate and irregular, the posterior marginal notches become less flaring and tend to close, the posterior edge changes from a truncated one to one more and more convexly rounded, the posterior end becomes at first relatively broader then relatively narrower than the anterior end, the height of the central mound and thickness of the margin increase, the corrugations on the upper surface become more accentuated, and irregularities appear in the poriferous zones. Lack of space forbids a more complete discussion of these features here; but a comparison of the figures given will bring them out in a stronger light. Specimen A, for instance, presents geruntic features, the effect of the elongation of the lunule in pushing out and rounding the posterior border, nearly closing the posterior notches and so changing the marginal outline as to make the form seem at least varietal in value if not a different species.

Related forms.—The only American fossil echinoid resembling this species is *E. tenuis* Kew,[2] from the upper Miocene or lower Pliocene of the Pacific coast. *E. macrophora* is easily separated by its larger lunule, shallower anterior notches, posterior petals curving around the lunule, and having the periproct at the edge of the lunule. The recent species *Encope grandis* L. Agassiz, reported by A. Agassiz [1] from the Gulf of California, is the most closely related to the present form, the very features which A. Agassiz notes as remarkable in *E. grandis* being those most characteristic of *E. macrophora*. *E. grandis* differs, however, in having all five marginal notches, and especially the three anterior ones, larger and more deeply incised, in having wider interporiferous areas, and the posterior margin concave. *Encope emarginata* Agassiz, a recent species from the coast of Brazil and the West Indies, is similar in general outline to *E. macrophora*, the young forms of the two species being quite similar, although the lunule of the young *E. macrophora* is usually more circular than that of the young *E. emarginata*. The older forms of *E. emarginata* also differ in that the marginal notches become lunules, a change which appears never to take place in *E. macrophora*. Possibly the present fossil form may be ancestral to *E. emarginata*. *Encope cixæ* De Cartázar, from the upper Miocene of Cuba, presents some points of similarity to the present species, but its lunule is smaller and more rectangular in form, its

[1] Revision of the Echini, p. 545 and Pl. XIII, fig. d.

[2] The description of *E. tenuis* Kew appeared while the present work was in press. See California Univ. Dept. Geology Bull., vol. 8, No. 5, pp. 47–48, Pl. I, fig. 1, and Pl. II, fig. 1, 1914.

posterior marginal notches are less pronounced and have one side merging into its more rounded posterior margin.

Localities.—Dr. Ravenel's plantation, known as "The Grove," on Cooper River, 17 miles from Charleston, and Goose Creek, S. C.; Alligator Creek, Monroe County, and near Punta Garda, Alligator Creek, Monroe County, Fla.

Geologic horizon.—Duplin marl, upper Miocene, in South Carolina, Caloosahatchee marl, Pliocene, in Florida.

Collections.—Academy of Natural Sciences of Philadelphia (1086, A); U. S. National Museum (164658, B; 9970, C); American Museum of Natural History; Boston Society of Natural History; Wagner Free Institute of Science.

Family CLYPEASTRIDÆ.

Genus CLYPEASTER Lamarck.

CLYPEASTER BOWERSI Weaver.

Plate XCVI, figures 1a–b.

Clypeaster bowersi Weaver, 1908, California Univ. Dept. Geology Bull., vol. 5, No. 17, pp. 271–272, Pl. XXI, fig. 1; Pl. XXII, fig. 1.
Clypeaster bowersi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 701.

Description.—As the writer has had no opportunity of studying the single specimen[1] of this large Clypeaster that has been discovered the description of Weaver is here given verbatim:

The test of this form is very large and thick. The largest specimens measured 119 millimeters in diameter. The outline seen from above is circular to elliptical. The margins are swollen and the summit very slightly elevated. On the posterior margin is a faint reentrant angle opposite the anal opening. The petals are broad and nearly closed at the extremity. The median interporiferous zones are broad, while the outer rows of pores converge at the ends so as almost to inclose them. The tuberculation is uniform on both the upper and lower surfaces and the tubercles are of nearly the same size over the whole test. The actinal surface is strongly concave and the actinostome deeply sunken. The ambulacral furrows are very deep and extend from the actinostome to the margin.

Dimensions.—Maximum width 100 millimeters; maximum length 119 millimeters; maximum thickness 37 millimeters.

Related forms.—Weaver makes the following remarks on related forms:

Clypeaster bowersi differs considerably from the other members of this genus on the Pacific coast. It is not far removed from *C. breunigei* Laube, which occurs in the Eocene in the Lybian Desert of Africa. *C. bowersi* is nearly twice as large as *C. breunigei* and is ellipsoidal in outline with thick margins, while the latter is pentagonal and has thin margins. The upper surface of the former is only slightly arched, while the apical system of the latter is conical and then gradually slopes to the margin. They differ also in the character of the petals and in the position of the anal pore. In *C. bowersi* the petals are broad and the poriferous zones lie nearly parallel. The anus is situated on the actinal surface at a distance from the margin about equal to its diameter.

Clypeaster bowersi shows a close relationship to *Diplothecanthus rosaceus* (Lamarck). It differs in that it is much flatter, the superior surface of *D. rosaceus* being more strongly convex. The actinostome of the former is sunken in a cavity which narrows gradually and is of much greater extent than in *D. rosaceus*. In *D. rosaceus* the ambulacral areas are more or less swollen and rise above the general level of the test, while in *C. bowersi* they are nearly at the same level as the interambulacral areas. The posterior ambulacral petals are the longest and the odd ambulacral petal is the shortest in *D. rosaceus*. In *C. bowersi* the odd ambulacral petal is the longest and the remaining four are of equal size.

Locality.—Colorado Desert (Weaver).[1]

Geologic horizon.—Associated with a fauna presumed to be of Miocene age (Weaver).[1]

Collection.—University of California.

[1] Since the above description was written William S. W. Kew has published some additional data relative to *C. bowersi* based on new material collected by him (California Univ. Dept. Geology Bull., vol. 8, No. 5, p. 50, Pls. IV, V, 1914). He supplements Weaver's description by mentioning that there are faint reentrant angles opposite all the interambulacral areas, that the petals are obovate, that the anterior petal is somewhat raised, and that the periproct is large, depressed, and inframarginal. Kew gives several new localities, all being near Coyote Mountain, Carrizo Creek region, California. He also says that *C. bowersi* occurs at all the localities in his lower division of the Carrizo Creek formation, the age of which has not yet been definitely determined. Arnold, in 1910 (Willis and Salisbury, Outlines of geologic history, p. 245), regarded the Carrizo Creek beds as equivalent to the Etchegoin formation which is now thought to be upper Miocene and lower Pliocene.

CLYPEASTER? BREWERIANUS (Rémond).

Plate XCVI, figures 2a–c, 3.

Echinarachnius brewerianus Rémond, 1863, California Acad. Sci. Proc., vol. 3, p. 53; no figure.
Echinarachnius brewerianus Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Echinarachnius brewerianus Gabb, 1869, Geol. Survey California, Paleontology, vol. 2, pp. 36, 109, Pl. XII, fig. 65, 65a.
Echinarachnius brewerianus Cooper, 1888, Cat. California fossils: State Mineralogist Seventh Rept., p. 271.
Clypeaster (?) *brewerianus* Merriam, 1899, California Acad. Sci. Proc., 3d ser., Geology, vol. 1, No. 5, p. 166, Pl. XXI, fig. 2.
Astrodapsis brewerianus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 702.

Determinative characters.—Test small, subelliptical to subcircular in marginal outline, faintly notched opposite posterior petals, longer than broad. The whole form is much depressed; upper surface somewhat convex, flattened near center, margin rather thick, rounded; apex central; under surface flat near margin, slightly concave near center. Ambulacral petals subequal, plates long and narrow, poriferous zones diverging from apical region to near margin, with a slight constriction about two-thirds the way. Apical system central. Peristome probably central. Periproct very small, subcircular, inframarginal, almost marginal.

Dimensions.—Specimen A: Length 32 millimeters; width 28 millimeters; height 9 millimeters. Specimen B; length 36 millimeters; width 31 millimeters; height 12 millimeters.

Description.—This species was described but not figured by Rémond as early as 1863, was first figured by Gabb in 1869; and was redescribed and refigured by Merriam in 1899. The test is small, rarely exceeding 1¼ inches in length. In marginal outline it is subelliptical to subcircular, faintly notched opposite posterior petals, longer than broad. The whole form is considerably depressed; the upper surface rising in gentle convex curves from the moderately thick, rounded margin to a flattened area near the centrally located apex; the under surface flat near the margin, slightly concave toward the center.

The ambulacral areas are wide, wider throughout than the interambulacral areas, the plates being long and narrow in the petaloid region and just at the margin; the dorsal portions petaloid. The petals are subequal in length, sharply pointed near the apical system, widening rapidly for two-thirds their length, then narrowing slightly and again widening rapidly to their ends where they are wide open. Several pairs of pores continue beyond the petals proper, diverging from the ends of the petals to the margin. The interporiferous areas are very wide, from three to four times as wide as the poriferous zones, flush or slightly tumid; poriferous zones very narrow near apical system, rather wide near ends of petals; pores oval, pairs conjugated.

The interambulacral areas are relatively narrow, very narrow near the apical system. The test is covered with small, nearly uniform tubercles, which are of nearly the same size on the upper and lower surfaces.

The apical system is central and coincident with the apex. The details can rarely be made out on the specimens.

The peristome and ambulacral grooves could not be clearly made out on the specimens studied. One fragment examined indicated that the peristome is small, central, or subcentral and circular.

The periproct is very small, subcircular, and inframarginal, almost marginal.

Related forms.—This species does not appear to be closely related to any other American species. It resembles *Astrodapsis tumidus* somewhat, as noted by Merriam, but lacks the alternating tumid petals and depressed interambulacral areas characteristic of that species. Until specimens showing the ambulacral grooves are found the generic position can not be determined with certainty.

Localities.—Near Lafayette, Concord quadrangle; 2 miles east of Walnut Creek House, Walnut Creek, Cal.

Geologic horizon.—"Upper Contra Costa Miocene," probably San Pablo formation, upper Miocene.

Collections.—University of California (19423, B); Academy of Natural Sciences of Philadelphia (1088, A).

Clypeaster? gabbi Rémond.

Clypeaster gabbi Rémond, 1863, California Acad. Sci. Proc., vol. 3, pp. 53, 54, no figure.
Clypeaster gabbi Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2
Clypeaster gabbi Gabb, 1869, Geol. Survey California, Paleontology, vol. 2, pp. 36, 109, Pl. XII, figs. 64, 64a.
Clypeaster gabbi Cooper, 1888, Catalogue of California fossils: State Mineralogist Seventh Rept., p. 271.
(?) *Scutella gabbi* Merriam, 1899, California Acad. Sci. Proc., 3d ser., Geology, vol. 1, No. 5, p. 168, Pl. XXII, figs. 5, 5a.

Description.—As the writer has been unable to examine any specimens which can be positively referred to this species, Rémond's description is given verbatim:

Disk rather small, comparatively thick, varying from circular to subpentagonal and irregular suboval. Apex nearly central, subelevated; margin rounded; genital apparatus subangular. Ambulacral star almost symmetrical; petals about equal in length, elongated, open at their extremities. Inferior surface flat near the edge and gently concave in the center. Mouth depressed, subcentral. Ambulacral furrows straight, slightly marked. Anal aperture very small, marginal. Tubercles of the upper surface numerous, especially in the ambulacra, round and prominent.

Dimensions.—According to Rémond the "greatest diameter is 1.16 inches, smallest diameter 1.10 inches, height 0.28 inch."

Related forms.—As Rémond unfortunately failed to figure his form, and as no specimens answering satisfactorily to his description are available, considerable uncertainty exists regarding this species and its relations to other Californian echinoids. As stated in the discussion of *Scutella gabbi* (Rémond) Merriam (p. 189), the form described and figured by Merriam differs in several important particulars which can not be ignored, and this renders it doubtful whether Merriam has described and figured identically the same form as Rémond. Additional collecting at Rémond's locality may result in discovering specimens answering to his description, otherwise the species must remain of doubtful character.

Locality and geologic horizon.—According to Rémond, this species "occurs abundantly on the eastern shore of San Pablo Bay, south of Mare Island, Cal., in soft sandstones of Miocene age."

Order ATELOSTOMATA.

Suborder ASTERNATA.

Family CASSIDULIDÆ.

Genus CASSIDULUS Lamarck.

Cassidulus bassleri Twitchell, n. sp.

Plate XCV, figures 5a-d.

Determinative characters.—Test small, subovate to subcircular in marginal outline, broadest posteriorly; upper surface convex, somewhat flattened on top, sides equally declining; margin rounded on the sides and anteriorly, somewhat angular at the rostrated posterior end; undersurface concave centrally. Apex central; apical system excentric anteriorly. Ambulacral areas rather broad in petaloidal dorsal portions, narrower elsewhere; poriferous zones broad, outer row of pores slitlike or elongate elliptical. Peristome small, central, pentagonal to substellate, with large well-defined floscelle. Periproct oval, situated rather high above the margin, in a short sulcus.

Dimensions.—Length 28 millimeters; width 25 millimeters; height 14 millimeters.

Description.—Specimens of this species have been known for some years; but it has usually been confused with the Cretaceous species *Cassidulus aquoreus* Morton and so labeled in the collections. It is named in honor of Ray S. Bassler, of the U. S. National Museum. The test is small, rarely exceeding an inch in diameter; subovate to subcircular in marginal outline, usually slightly broader posteriorly than anteriorly and slightly longer than broad. The upper surface is moderately elevated, the height being equal to about half the diameter, convex, somewhat flattened on top from above the periproct to the apical system, equally declining anteriorly and on the sides, posteriorly it slopes from above the periproct to the margin in a steep, oblique,

nearly straight line; margin rounded along the sides, less so at the anterior end, somewhat angular at the rostrated posterior end; undersurface flattened, concave centrally. The apex is central or subcentral.

The ambulacral areas are rather broad in the petaloid dorsal portions, less so at the ambitus, and narrow at the ends of the petals and actinally; the petals are relatively large, broad, subequal in length, extending two-thirds or more of the distance to the ambitus; the poriferous zones are broad, though less so than the interporiferous areas, outer row of pores slitlike or elongate elliptical, inner row round, pairs of pores conjugate.

The surface of the test is closely set with small imperforate tubercles set in deep scrobicules. The tubercles increase in size on the undersurface except along a median band which is somewhat smooth but dotted with numerous granulations.

The apical system is excentric anteriorly. There are four genital pores, the anterior pair being nearer together than the posterior. The right anterior genital plate, which is modified to form the madreporite, is very large, occupying the larger part of the system. There are five small radial plates, each perforated by a small pore.

The peristome is small, central, pentagonal to substellate, with a large floscelle with prominent bourrelets and well-defined, broad, oval phyllodes.

The periproct is oval, or subelliptical, longitudinally elongate, in a short sulcus situated rather high above the posterior margin. The ends of the posterior petals are about opposite the middle of the periproct.

Related forms.—This species is similar in a number of features to *Cassidulus berryi*, but it is more elevated, has a more rounded margin and has its peristome central instead of anteriorly excentric. It also presents interesting resemblances to the Cretaceous species *C. æquoreus*, and *C. micrococcus*, but can be separated from the former by its more subcircular marginal outline, its central peristome, the slightly higher position of its periproct, and the more elongate character of the outer row of pores of its petals, and from the latter by its much smaller size, its relatively larger floscelle, and the somewhat lower position of its periproct.

Locality and geologic horizon.—The specimens on which this species is founded are said to be from the Miocene of North Carolina. They can not be more definitely located.

Collection.—U. S. National Museum (9476).

Galerites oregonensis Dana.

Galerites oregonensis Dana, 1849, Repr. U. S. Expl. Exped., Geology, vol. 10, p. 729, Pl. II, figs. 5, 6, 6a.
Galerites oregonensis Gabb, 1869, Geol. Survey of California, Paleontology, vol. 2, p. 123.

This species was based by J. D. Dana on a few fragments and spines obtained from the argillaceous Astoria shale of the lower Miocene of Oregon. The spines are said to be "half an inch long, very slender, delicately striate, with the striæ punctate or subcrenulate." No description of the test is given and Dana himself said the "specimens are so imperfect that we refer it with hesitation to the genus Galerites." In view of the imperfect character of the specimens, the acceptance of the species is reserved until additional material has been obtained.

Suborder STERNATA.

Family SPATANGIDÆ.

Genus AGASSIZIA Valentin.

Agassizia porifera (Ravenel).

Plate XCVII, figures 1a–d.

Brissopsis poriferus Ravenel, 1848, Echinidæ, recent and fossil, South Carolina, p. 4, Pl. II, figs. 5, 6.
Brissopsis poriferus Ravenel, 1850, Am. Assoc. Adv. Sci. Proc., vol. 3, p. 160.
Agassizia porifera McCrady, 1857, Pliocene fossils, South Carolina, pp. 5, 6, Pl. I, fig. 5, Pl. II, fig. 4.
Agassizia porifera Meek, 1864, Check list, Miocene, p. 2.
(?) *Agassizia excentrica* A. Agassiz, 1872, Revision of the Echini, pt. 1, p. 88.
Agassizia porifera A. Agassiz, 1874, Revision of the Echini, pt. 4, p. 751.
Agassizia porifera Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 707.

Determinative characters.—Test moderate, ovoid, tall, apex slightly excentric forward, no anterior groove, nearly flat below. Ambulacra narrow, paired in shallow grooves, anterolateral much longer than the posterolateral; pairs small, slitlike. Interambulacra broad, covered with very small tubercles. Fascioles indistinct. Peristome near forward margin.

Dimensions.—Length 42 millimeters; width 37 millimeters; height 35 millimeters.

Description.—This species was figured by Ravenel in 1848, and described and figured by McCrady in 1858. The test is of moderate size, ovoid, and tall. The apex is slightly excentric forward. There is no anterior groove, a slight depression extending from the apex part way to the margin. The lower surface is nearly flat.

The ambulacra are narrow, the posterolateral pair bent outward toward the margin. The anterolateral nearly straight. The paired ambulacra in shallow depressions, long, open below, the posterolateral shorter than the anterolateral pair.

The interambulacra are wide, the paired interambulacra slightly gibbous at their upper ends. Portions of the peripetalous and lateral fascioles are rather indistinctly shown.

The peristome is near the anterior margin with a well-developed labrum. The periproct is not shown on the single specimen of this species studied.

Locality.—Near Oakley Inlet, Waccamaw, S. C.

Geologic horizon.—Miocene.

Collection.—American Museum of Natural History.

Genus ECHINOCARDIUM Gray.

ECHINOCARDIUM ORTHONOTUM Conrad.

Plate XCVII, figs. 2a–c; Plate XCVIII, figs. 1a–c, 2a–c.

Spatangus orthonotus Conrad, 1843, Acad. Nat. Sci. Philadelphia Proc., vol. 1, p. 327.
Amphidetus virginianus Forbes, 1845, Geol. Soc. London Quart. Jour., vol. 1, pp. 425, 426, 3 figs.
Amphidetus virginianus Forbes, 1846, Geol. Soc. London Proc., vol. 6, pp. 559, 560, 3 figs.
Amphidetus orthonotus Tuomey and Holmes, 1855, Pliocene fossils, South Carolina, pp. 6, 7, figs. 1, 1a–c.
Amphidetus virginianus Emmons, 1858, North Carolina Geol. Survey Rept., p. 310, fig. 245a–c.
Echinocardium virginianum Desor, 1858, Synopsis échinides fossiles, p. 408.
Echinocardium orthonotus Conrad, 1865, Acad. Nat. Sci. Philadelphia Proc., vol. 17, p. 75.
(?) *Echinocardium pennatifidum* A. Agassiz, 1872, Revision of the Echini, pt. 1, p. 111.
Echinocardium orthonotum A. Agassiz, 1874, Revision of the Echini, pt. 4, p. 751.
Amphidetus virginianus Schluter, 1899, Deutsche Geol. Gesell. Zeitschr., vol. 51, p. 113.
Echinocardium orthonotum Clark, 1904, Maryland Geol. Survey, Miocene, pp. 430–432, Pl. CXIX, figs. 1a–c.
Echinocardium orthonotum Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 706.

Determinative characters.—Test large, ovate to cordiform, elevated, upper surface nearly flat forward, deep and broad, anterior groove higher posteriorly with truncated surface, tumid plastron below. Ambulacra wide, anterior in broad groove, paired ambulacra in shallow grooves triangular in outline, widely open above, narrow below; pore pairs large and not numerous. Interambulacra narrow above, wide below; fascioles distinct. Peristome large, slitlike. Periproct high on posterior truncation.

Dimensions.—Specimen A: Length 58 millimeters; width 52 millimeters; height 29 millimeters. Specimen B: Length 51 millimeters; width 46 millimeters; height 29 millimeters.

Description.—This species was first described by Conrad in 1843, but not figured. Forbes, in 1845, redescribed and figured the form under the name of *Amphidetus virginianus*. The test is rather large, irregularly ovate to cordiform, elevated but more posteriorly than anteriorly. The upper surface is mostly flat forward. A broad and rather deep anterior groove with slightly gibbous edges indents the upper surface but narrows and shallows toward the margin. The posterior portion is elevated into a broad ridge which continues nearly to the truncated posterior margin. The lower surface is nearly flat except for the elevated plastron.

The ambulacra are wide, the anterior being situated in the broad anterior groove. The paired ambulacra are situated in shallow grooves on the upper surface. They are triangular in outline, widely open above and narrow below, the anterolateral being wider above than the

posterolateral. The pore pairs are large and not numerous. They appear again on the lower surface near the peristome.

The interambulacra are narrow above and widen rapidly. They have numerous large tubercles below which become few and irregularly scattered above the lower margin. The fasciole can be plainly traced.

The apical system is small. The peristome is large and slitlike, very much elongated transversely. The periproct is moderate in size, high on the posterior truncation.

Locality.—James River, Va.

Geologic horizon.—Yorktown formation, upper Miocene.

Collections.—Academy of Natural Sciences of Philadelphia (1079); American Museum of Natural History; U. S. National Museum; Johns Hopkins University (T. 1002).

Echinocardium depressum Clark, n. sp.

Plate XCVIII, figures 3a–c.

Determinative characters.—Test moderate, cordiform, low, depressed, both upper and lower surfaces nearly flat, anterior groove shallow, posterior truncation. Ambulacra wide, anterior in shallow groove, paired in grooves, triangular in outline, open above, narrow below. Interambulacra narrow above, widening rapidly toward the ambitus. Peristome small.

Dimensions.—Length 40 millimeters; width 37 millimeters; height 13 millimeters.

Description.—This species is represented only by casts, which, however, are very different in their characters from *E. orthonotum*, the only other Miocene representative of this genus from American deposits. The test is of moderate size, cordiform, low, much depressed, nearly flat. The anterior groove is shallow and broad. The posterior margin is truncated.

The ambulacra are wide, the paired ambulacra being situated in shallow grooves triangular in outline. They are open above and narrow below. The interambulacra are narrow above, forming a very obtuse angle, but widening rapidly below toward the ambitus. The fascioles are absent. The peristome is small and apparently transversely elongated.

Locality.—Near old Chattahoochee Landing, Apalachicola River, Fla.

Geologic horizon.—Lower Miocene.

Collection.—U. S. National Museum (164454).

Echinocardium gothicus (Ravenel).

Amphidetus gothicus Ravenel, 1848, Echinidæ, recent and fossil, South Carolina, p. 4 and figure.
Amphidetus ampliphorus McCrady, 1855, Pliocene fossils, South Carolina, pp. 7, 8, Pl. II, fig. 2.
Amphidetus gothicus McCrady, 1855, Pliocene fossils, South Carolina, pp. 7, 8, Pl. II, fig. 3.
(?) *Echinocardium cordatum* A. Agassiz, 1872, Revision of the Echini, pt. 1, pp. 109, 110.
Amphidetus gothicus A. Agassiz, 1874, Revision of the Echini, pt. 4, p. 751.
Echinocardium ampliflorus, Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 707.
Echinocardium gothicum Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 707.

Description.—No material has been secured and it is therefore impossible to satisfactorily describe this species. A. Agassiz regards *E. gothicus* and *E. ampliphorus* as the same species and refers it doubtfully to *E. cordatum*, which is found widely distributed in the Atlantic Ocean to-day.

Locality.—The Grove, Cooper River, S. C.

Geologic horizon.—Duplin marl, upper Miocene.

Collection.—Unknown.

Genus LINTHIA Merian.

Linthia? californica Weaver.

Plate XCVIII, figure 4.

Linthia (?) *californica* Weaver, 1908, Univ. California Dept. Geology Bull., vol. 5, No. 17, pp. 272, 274, Pl. XXI, fig. 2.
Brissopsis californica Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 705.

Description.—Weaver says:

The outline of the test from above is elliptical. The anterior groove is deep. The apical system is small and situated slightly anterior to the center. The central portion of the lateral interambulacral plates forms a series of irregular ridges extending from the apical system to the margin. The posterior interambulacral area is elevated. The three anterior ambulacra are nearly equal in size and larger than the posterior areas as far as known. The poriferous zones of the ambulacra are narrow, but the pores are large. The specimen is a poorly preserved cast and further data are lacking. This species has been referred to Linthia rather than to Schizaster on account of the more central position of the apical system.

Dimensions.—Length 19 millimeters; width 14 millimeters; height 7 millimeters.
Locality.—One mile west of Bear Valley, Contra Costa County, Cal.
Geologic horizon.—Lowest member of the Monterey shale, middle Miocene.
Collection.—University of California.

Genus BRISSUS Leske.

Brissus spatiosus (Ravenel).

Pericosmus spatiosus Ravenel, 1848, Echinidæ, recent and fossil, South Carolina, p. 4.
Hemiaster (Pericosmos) spatiosus Ravenel, 1850, Am. Assoc. Adv. Sci. Proc., vol. 3, p. 160.
Brissus spatiosus McCrady, 1855, Pliocene fossils, South Carolina, p. 8, Pl. III, figs. 1, 1a–c.
Brissus spatiosus Meek, 1864, Check list, Miocene, p. 2.
Meoma ventricosa A. Agassiz, 1872, Revision of the Echini, pt. 1, p. 143.
Meoma spatiosa Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 707.

Description.—This species, which was named by Ravenel, was subsequently figured and described by McCrady. It is regarded by A. Agassiz as a synonym of *Meoma ventricosa*. No specimens have been found for the present study, and in the absence of material it is difficult to determine the true relations of the species, although it may well belong to the genus Meoma.
Locality.—The Grove, Cooper River, S. C.
Geologic horizon.—Duplin marl, upper Miocene.
Collection.—Unknown.

Genus METALIA Gray.

Metalia raveneliana (McCrady).

Plagionotus ravenelianus McCrady, 1855, Pliocene fossils, South Carolina, pp. 10, 11, Pl. III, figs. 3, 3a.
Plagionotis ravenelianus Meek, 1864, Check list, Miocene, p. 2.
Plagionotus ravenelianus A. Agassiz, 1874, Revision of the Echini, pt. 4, p. 751.
Plagiobrissus ravenelianus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 707.

Description.—No material has been secured and it is therefore impossible to satisfactorily describe this species. The genus Plagionotus is now regarded as a synonym of Metalia.
Locality.—The Grove, Cooper River, S. C.
Geologic horizon.—Duplin marl, upper Miocene.
Collection.—Unknown.

Metalia holmesi (McCrady).

Plagionotus holmesii McCrady, 1855, Pliocene fossils, South Carolina, pp. 9, 10, Pl. III, figs. 2, 2a.
Plagionotus holmesii Meek, 1864, Check list, Miocene, p. 2.
Plagionotus holmesii A. Agassiz, 1874, Revision of the Echini, pt. 4, p. 751.
Plagiobrissus holmesi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 707.

Description.—No material has been secured and it is therefore impossible to satisfactorily describe this species. The genus Plagionotus is now regarded as a synonym of Metalia.
Locality.—Goose Creek, S. C.
Geologic horizon.—Duplin marl, upper Miocene.
Collection.—Unknown.

PLIOCENE ECHINODERMATA.

Class ECHINOIDEA.

Subclass REGULARIA ECTOBRANCHIATA.

Order DIADEMOIDEA.

Suborder ECHININA.

Family STRONGYLOCENTROTIDÆ.

Genus STRONGYLOCENTROTUS Brandt.

STRONGYLOCENTROTUS DRÖBACHIENSIS (Müller).

Plate XCIX, figures 1a–c.

Description.—Two specimens have been examined from the Pliocene beds of Caloosahatchie River that evidently belong to this common and widespread Recent species. The characters are similar to those of living forms, and it seems therefore that the specimens must be regarded as representing the same species. A. Agassiz[1] points out the great variability in the different individuals of the species, forms much more extreme than those of the two Pliocene specimens studied occurring.

Dimensions.—Diameter 55 millimeters; height 27 millimeters.

Locality.—Caloosahatchie River, Fla.

Geologic horizon.—Pliocene.

Collection.—Wagner Free Institute of Science (4350).

Subclass IRREGULARIA.

Order GNATHOSTOMATA.

Suborder CLYPEASTRINA.

Family SCUTELLIDÆ.

Genus DENDRASTER Agassiz.

DENDRASTER INTERLINEATUS (Stimpson).

Plate C, figures 2a–b.

Scutella interlineata Stimpson, 1856, Pacific Railroad Repts., vol. 5, pp. 153, 154. Pl. IV, fig. 30.
Scutella interlineata Rémond, 1863, California Acad. Nat. Sci. Proc., vol. 3, pp. 14, 15.
Scutella interlineata (Blake) Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Scutella interlineata Gabb, 1869, Geol. Survey California Rept., Paleontology, vol. 2, p. 110.
Scutella interlineata Cooper, 1888, Cat. California fossils: State Mineralogist Seventh Rept., p. 271.
Scutella interlineata Merriam, 1899, California Acad. Nat. Sci. Proc., 3d ser., Geology, vol. 1, No. 5, p. 169, Pl. XXII, fig. 6.
Dendraster (?) *interlineatus* Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 706.

Description and determinative characters.—The writer has been unable to secure for study more than a few specimens of this species. Among these is Stimpson's type—a greatly weathered and fragmentary specimen. As Merriam, on the other hand, has had considerable material to work with, his description is here repeated:

Test pentagonal to circular, angular or truncated posteriorly, somewhat arched above; summit nearly central and in front of the excentric apical system, specimens ranging up to over 120 millimeters in diameter.

[1] Revision of the Echini, pp. 277–281.

Ambulacra rather broad, of unequal length, anterior three of about the same length and longer than the posterior pair. Anterior petal open at the end, the others nearly closed. Few if any pores continuing beyond the ends of the petals.

The distance from the excentric apical system to the posterior margin is to the distance to the anterior margin as 1 to 1.5. The anus is supramarginal, being separated from the margin in adult specimens by about the width of one of the marginal interambulacral plates.

No specimens have been seen by the writer in which the ambulacral furrows are well shown. On such specimens as show the lower side, the furrows seem to be dichotomously divided near the mouth. This agrees with Rémond's description, which also states that the furrows are not as well marked nor as much branched as in *Dendraster excentricus*.

The spines of the upper surface are about 1 millimeter long; they are longitudinally striated and at the distal end are strongly swollen and obliquely truncated or bent. The spines of the lower surface are slender striated rods about 2 to 3 millimeters long. The tubercles differ little in size on the upper and lower surfaces.

The internal skeleton comprises numerous irregular pillars and plates near the margin and a pair of radial plates in each interambulacral space.

Dimensions.—The specimens vary from small to large, ranging, according to Merriam, up to 120 millimeters in diameter. The specimen figured gave: Length 56 millimeters; width 56 millimeters; height 5 millimeters.

Related forms.—*D. interlineatus* is very closely related to *D. oregonensis*. There appear to be differences, however, which justify the separation of the two forms, to judge from the specimens studied. *D. oregonensis* is to be distinguished by the details of its ambulacral petals. In both the anterior and posterior paired petals the posterior poriferous zones are straight, while in *D. interlineatus* all are curving, or at most only the posterior zones of the posterior pair become nearly straight. In *D. oregonensis* all of the petals are well open at the ends, the poriferous zones converging slightly or not at all toward the ends and diverging sharply at the ends, with several pairs of pores occurring between the ends of the petals and the margin; while one of the most striking characters of *D. interlineatus* is the curving around abruptly toward each other of the poriferous zones so as to practically close the petals in all but the anterior petal. *D. oregonensis* differs further in having less symmetrically subelliptical petals, in being relatively higher in proportion to its width, and in having a relatively larger periproct.

D. interlineatus also resembles *S. fairbanksi* and *S. gabbi;* but both of these forms can be easily distinguished by the central or slightly anteriorly excentric position of their apical systems, their relatively smaller and more equal petals, and their wider marginal areas.

Locality.—In the sea cliffs about one-fourth mile above Mussel Rock (figured specimen); south of Point Lobos, near San Francisco (type); Ano Nuevo Creek, near Felt Lake and in the sea cliffs between Santa Cruz and Capitola, and at Rio Dell Diller, Cal. (Arnold).

Geologic horizon.—Merced formation, upper Pliocene.

Collections.—U. S. National Museum; University of California (19427).

Genus ASTRODAPSIS Conrad.

Astrodapsis fernandoensis Pack.

Plate CI, figures 1, 2.

Astrodapsis fernandoensis Pack, 1909, California Univ. Dept. Geology Bull., vol. 5, No. 18, p. 279, Pl. XXIV, figs. 3, 4.
Astrodapsis fernandoensis Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 706.

Description.—As the writer has had no opportunity to study any specimens of this species, the description of Pack will be given in full.

Test small; suboval in outline, anterior end rounded, posterior end slightly pointed; much depressed, upper surface very slightly convex, apex central; edges rounded. Apical system central; petals extend to margin, wide open at the end, raised near the apical system but almost flush with the surface of the test near the margin. Poriferous zones very narrow, together forming about one-fourth the width of the petal. The two posterior petals are gently convex toward the median line through the posterior interambulacral space. A broad, shallow depression occupies the center of the interambulacral areas; the two secondary depressions so prominent in *Astrodapsis antiselli* are almost entirely lacking. Actinal surface gently concave, furrows poorly marked, but apparently branched as in *Astrodapsis antiselli*. Anal pore submarginal, large, and oval in outline. The posterior end of the test is produced beyond the pore to a small point, particularly noticeable in the smaller specimens. Tubercles very large, and set in well-defined pits apparently the same on upper and lower surfaces.

Dimensions.—Length 51 millimeters; width 39 millimeters; height 8 millimeters.

Related forms.—Judging from Pack's figures and description *A. fernandoensis* is very closely allied to *A. antiselli* Conrad, the most notable points of resemblance being the oval outline, the slight pointing of the posterior end, the rounded edges and the slight convexity of the upper surface. The points of resemblance are so striking as to raise the question, whether *A. fernandoensis* ought not to be regarded as a synonym of *A. antiselli*; but as Pack does not state that the margin of *A. fernandoensis* is very thick and as the figures suggest a greater contrast between the elevation of its ambulacral ridges and the depth of its interambulacral depressions than occurs in *A. antiselli*, decision is reserved until authentic specimens of Pack's form can be examined.

Locality.—Elsemere Canyon, Los Angeles County, Cal.

Geologic horizon.—Fernando formation, lower Pliocene beds.

Collection.—University of California (A, B).

Family CLYPEASTRIDÆ.

Genus DIPLOTHECANTHUS Duncan.

DIPLOTHECANTHUS DALLI Twitchell, n. sp.

Plate XCIX, figures 2a–b; Plate C, figures 1a–b.

Determinative characters.—Test large; pentagonal in marginal outline, longer than broad, broadest opposite the ends of the anterior petals, pointed anteriorly, posterior end truncated centrally; upper surface irregularly convex, high, highest back of center, whence sloping gently and in a straight line to the blunt, tumid anterior edge and quite steeply and in a straight line to the thinner, wedge-shaped posterior edge; under surface deeply concave, the concavity beginning near the margin and increasing at first gradually then rapidly to the center. Ambulacral petals large, broad, very tumid, almost reaching the margin, nearly closing, the posterior pair slightly longer than the odd petal which is slightly longer than the anterior pair. Apical system central, sloping downward anteriorly; five genital pores a short distance from the slightly depressed madreporite. Peristome large, slightly excentric posteriorly, subpentagonal, deeply sunken; ambulacral furrows simple, straight, reaching the margin. Periproct rather large, subcircular; inframarginal, almost marginal.

Dimensions.—Length 112 millimeters; width 92 millimeters; height 50 millimeters.

Description.—Only a few specimens of this handsome clypeastroid form have been discovered. The test is large; pentagonal in marginal outline, the corners of the pentagon being rounded and the sides straight or faintly concave; longer than broad, broadest opposite the ends of the anterior petals, pointed anteriorly, posterior end truncated centrally; margin very thick and rounded opposite the petals, thinner between them, thinnest along the wedge-shaped posterior edge. The upper surface is irregularly convex, high, relatively higher than in other American clypeastroid forms. The apex is slightly excentric posteriorly, being located at the posterior part of the apical system from which point the upper surface slopes gently (the angle being about 30° from the horizontal), and in a straight line to the wedge-shaped posterior margin. The outline along a longitudinal median section is therefore angular at the apex. The under surface is strongly concave; the concavity beginning near the margin and increasing gradually for about half the way, then very rapidly for the rest of the way to the deeply sunken peristome, where it is about one-half the height of the test. The rapid increase in the concavity begins somewhat farther from the anterior end than it does elsewhere.

The ambulacral areas are wide, the dorsal portions petaloid. The petals are very large and conspicuous, broad, very tumid, almost reaching the margin, nearly closed at the ends, the posterior pair slightly longer than the odd petal which is slightly longer than the anterior pair. The poriferous zones are wide, narrowing and converging rapidly at the ends so as to almost completely inclose the interporiferous area, the inner row of pores notably higher than the outer row; pores round, subequal, pairs of pores conjugated. The interporiferous areas are very wide, very tumid, the inner portions uniting to form a narrow tumid ring around the madreporite.

The interambulacral areas are narrow throughout their whole length, though wider between the ends of the petals than elsewhere, much narrower than the ambulacral areas. The whole surface of the test is thickly set with small tubercles which are somewhat larger on the under surface.

The apical system is central, sloping downward anteriorly from the apex; the madreporite large, pentagonal, slightly depressed. There are five genital pores situated a short distance from the madreporite; and there are five small radial plates at the edge of the madreporite, perforated by minute pores.

The peristome is large, subpentagonal, slightly excentric posteriorly at the deepest point of the deep concavity on the under surface. The ambulacral furrows are simple, straight shallow grooves extending from the peristome almost to the margin, which are deeper midway than toward the peristome.

The periproct is rather large, circular, inframarginal, almost marginal.

Related forms.—*D. dalli* is very closely related to the recent American form generally known as *Echinanthus rosaceus* (which, if Duncan be followed, should be *Diplothecanthus rosaceus*), differing from it chiefly in being relatively higher, in having the apex slightly excentric posteriorly and angular, with a straighter slope anteriorly and a steeper slope posteriorly, in having the apical system sloping downward anteriorly, and in having the interporiferous areas more tumid and coalescing around the madreporite. *D. dalli* rather closely resembles in many features the foreign forms *Clypeaster crassicostatus*[1] Agassiz, from the Miocene of Austria-Hungary, Italy, and Corsica, but differs from it in being less elongate longitudinally and more elevated, in having more difference between its anterior and posterior slope, and in having its petals broader, slightly less open and somewhat longer.

Locality.—Near Fort Thompson, Caloosahatchee River, Fla.

Geologic horizon.—Caloosahatchee marl, Pliocene.

Collection.—U. S. National Museum (164670). Collected by W. H. Dall, after whom the species is named.

Diplothecanthus rosaceus (Lamarck).

Plate CII, figures 1a–b; Plate CIII, figures 1a–b

Echinus reticulatus Linné, 1758, Systema naturæ, p. 3191.
Clypeaster rosaceus Lamarck, 1840, Animaux sans vertèbres, 2d ed., p. 289.
Echinanthus rosaceus A. Agassiz, 1872, Revision of the Echini, pp. 106, 311, 514.

Description.—This well-known recent species is so fully described elsewhere it is needless to give a detailed description here. The specimen here figured was reported as found in the Pliocene deposits of Florida. The test is very large; pentagonal in marginal outline, the corners of the pentagon being rounded and the sides and posterior end slightly concave; somewhat longer than broad, pointed anteriorly; margin thick and rounded opposite the petals, less so between them. The upper surface is convex, moderately high, of uniform height at the highest parts of each of the petals. The apex is central, coincident with the apical system, and the upper surface is nearly level for nearly an inch out from the center in rather steep curves along the ambulacral areas and in steep nearly straight lines along the interambulacral areas to the margin. The outline along a longitudinal median section is nearly level for the central third of the length of the test whence it slopes nearly equally to each end. The under surface is nearly flat around the margin and rather strongly concave around the peristome, where it is less than one-half the height of the test.

The ambulacral areas are very wide, the dorsal portions petaloid. The petals are very large, very broad, moderately tumid, well apart at the ends, subequal in length. The poriferous zones are very wide, the inner row of pores moderately elevated above the outer.

The interambulacral areas are very narrow, especially at the margin, where they are only about one-third as wide as the ambulacral areas.

[1] See Michelin's Monographie des Clypéastres, p. 115, Pl. XVII, figs. 1a–f.

The apical system is central, coincident with the apex, about on a level with the highest portions of the ambulacral petals. The specimen is too weathered to permit of making out the details.

The peristome is large, subpentagonal, central, at the deepest point of the concavity on the under surface. The ambulacral furrows are simple, straight shallow grooves extending from the peristome nearly to the margin.

The periproct is large, circular, inframarginal, almost marginal.

Dimensions.—Length 134 millimeters; width 116 millimeters; height 50 millimeters.

Related forms.—It is unnecessary to discuss here the related recent forms. The nearest fossil form is *Diplothecanthus dalli,* which is to be distinguished by being relatively higher, in having the apex slightly excentric posteriorly and angular, with a straighter slope anteriorly and a steeper slope posteriorly, in having the apical system sloping downward anteriorly, and in having the interporiferous areas more tumid and coalescing around the madreporite.

Locality.—Near Labelle Landing, Caloosahatchee River, Fla.

Geologic horizon.—Pliocene (?).

Collection.—U. S. National Museum (165693).

Order ATELOSTOMATA.

Suborder ASTERNATA.

Family CASSIDULIDÆ.

Genus CASSIDULUS Lamarck.

CASSIDULUS BERRYI Twitchell, n. sp.

Plate CI, figures 3a–d.

Determinative characters.—Test small, subcircular in marginal outline; upper surface much depressed, convex; sides and ends equally and gently declining; margin angular; posterior end rostrated; under surface concave, more so anteriorly around the peristome. Apex central; apical system excentric anteriorly. Ambulacral areas rather broad in petaloidal dorsal portions, very narrow above the margin. Peristome small, anteriorly excentric, pentagonal, with a floscelle. Periproct oval, supramarginal, in a short, shallow sulcus.

Dimensions.—Length 28 millimeters; width 27 millimeters; height 11 millimeters.

Description.—The only specimen of this species so far reported was found recently in North Carolina by E. W. Berry, of Johns Hopkins University, in whose honor the species is named. Unfortunately, the specimen is damaged, so that a number of important details can not be made out; but the characters which can be made out prove it to be distinct from the other American representatives of the genus. The test is small, about an inch in diameter; subcircular in marginal outline, the longitudinal diameter slightly exceeding the transverse. The upper surface is much depressed, convex, sides and ends equally and gently declining; margin rather sharply angular all around; posterior end rostrated and faintly notched beneath the periproct; under surface concave, more so anteriorly around the peristome than elsewhere. The apex is central.

The ambulacral areas are rather broad in the petaloid dorsal portions, very narrow above the margin and actinally; the petals are rather broad, subelliptical, subequal in length, nearly closing at the ends. The details are obscure.

The apical system is excentric anteriorly. The details can not be made out on the specimen.

The peristome is small, anteriorly excentric, beneath the apical system, pentagonal, with a floscelle having prominent bourrelets.

The periproct is oval, longitudinally elongate, supramarginal, in a short, rather wide, shallow sulcus, which extends to and faintly notches the posterior margin.

Related forms.—The nearest related American form is *Cassidulus bassleri*, from which it is readily distinguished by its more depressed form, its angular margin, and the anteriorly excentric position of its peristome.

Locality.—Neills Eddy Landing, Cape Fear River, N. C.

Geologic horizon.—Waccamaw marl, Pliocene.

Collections.—U. S. National Museum; Johns Hopkins University (T 1).

Suborder STERNATA.

Family SPATANGIDÆ.

Genus SCHIZASTER Agassiz.

SCHIZASTER (?) STALDERI Weaver.

Plate CIII, figure 2.

Schizaster (?) *stalderi* Weaver, 1908, California Univ. Dept. Geology Bull., vol. 5, No. 17, p. 274, Pl. XXI, fig. 3.
Schizaster stalderi Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 705.

Description.—Weaver says:

> Test distinctly cordate in form, with all of the petals deeply sunken. The depression of the anterior petal deeply notches the anterior margin. The petals of the bivium are very short. The mouth opening is situated very far forward. The anal opening is not shown. As all of the known specimens are casts, the nature of the plates of the test is only imperfectly shown.

Dimensions.—Maximum length 30.5 millimeters; maximum width 28 millimeters.

Locality.—Humboldt County, Cal.

Geologic horizon.—Wildcat series of Lawson, Pliocene.

Collection.—University of California.

PLEISTOCENE ECHINODERMATA.

Class STELLEROIDEA.

Subclass ASTEROIDEA.

Order CRYPTOZONIA.

Family ASTERIIDÆ.

Genus ASTERIAS Linné.

ASTERIAS STELLIONURA Poiret.

Asterias stellionura Sears, 1905, Physical geography, etc., Essex County, Mass., pp. 369, 370.

Description.—Sears describes the discovery in 1903 in the Richard Graham clay pit at Lynn, Mass., of a thick bed of fossil starfish, material from which was collected and sent to A. E. Verrill, of Yale University, for identification. Of the two forms found one is unquestionably referred to *A. stellionura*. Verrill states that "the pedicellariæ, both major and minor, are remarkably well preserved and very characteristic," and that "it is a very arctic species, common at Spitzbergen and the northern Norwegian coasts."

Locality.—Richard Graham clay pit, Lynn, Mass.

Geologic horizon.—Pleistocene.

Collection.—Peabody Museum, Salem, Mass.

ASTERIAS LINCKI Müller.

Asteracanthion lincki Sears, 1905, Physical geography, etc., Essex County, Mass., pp. 369, 370, fig. 202.

Description.—Verrill says:

> The pedicellariæ, both major and minor, are remarkably well preserved and very characteristic. On the Asteracanthion the latter form large and dense clusters around all the spines. The same appears in your fossils. The major ones are very large, ovate, subacute, especially along the adambulacral plates, but also many of the dorsal surfaces as in your examples. Dorsal plates are very delicate and form a slender network. Adambulacral spines are small and slender, tapered, acute, and a large tubed spine stands singly back of every fourth or fifth plate (sometimes third or fourth) as in yours. In all of these characters and others it differs from *A. vulgaris*.

Locality.—Richard Graham clay pit, Lynn; Liberty Street, Danvers, Mass.

Geologic horizon.—Pleistocene.

Collection.—Peabody Museum, Salem, Mass.

Class ECHINOIDEA.

Subclass REGULARIA ECTOBRANCHIATA.

Order DIADEMOIDEA.

Suborder ECHININA.

Family TRIPLECHINIDÆ.

Genus TOXOPNEUSTES A. Agassiz.

TOXOPNEUSTES VARIEGATUS (Lamarck).

Echinus variegatus Holmes, 1858, Post-Pliocene fossils South Carolina, Pl. II, fig. 1.
Anapesus carolinus Holmes, 1858, Post-Pliocene fossils South Carolina, Pl. II, fig. 2.
Toxopneustes variegatus A. Agassiz, 1872, Revision of the Echini, p. 168.

Description.—A. Agassiz regards the form referred by Holmes to *Anapesus carolinus* as *T. variegatus*. No material has been available for study.

Locality.—Simmons Bluff, St. Paul's, Wando, and Charleston, S. C. (Holmes).

Geologic horizon.—Pleistocene.

Collection.—Unknown.

Family STRONGYLOCENTROTIDÆ.

Genus STRONGYLOCENTROTUS Brandt.

STRONGYLOCENTROTUS DRÖBACHIENSIS Müller.

(?) *Echinus granulatus*, Billings, 1856, Canadian Naturalist and Geologist, 1st ser., vol. 1, p. 346.
Strongylocentrotus dröbachiensis Verrill, 1875, Am. Jour. Sci., 3d ser., vol. 10, p. 375.
Strongylocentrotus dröbachiensis Cooper, 1894, California Min. Bur. Bull. 4, p. 32.

Description.—Fragments of tests and spines regarded as representing this species have been reported from Pleistocene deposits from Nantucket northward and also in California.

Localities.—Canada (Billings); Sankaty Head, Nantucket, Mass. (Verrill); San Nicolas Island, Cal. (Burns).

Geologic horizon.—Pleistocene.

Collection.—Unknown.

STRONGYLOCENTROTUS FRANCISCANUS A. Agassiz.

Strongylocentrotus franciscanus Arnold, 1903, California Acad. Sci. Mem., vol. 3, p. 90.
Strongylocentrotus franciscanus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 706.

Description.—Arnold in discussing the occurrence of this species in the Pacific coast Pleistocene says:

> This is the large sea urchin of the west coast. Spines which are probably of this species have been found in the lower San Pedro series of Deadman Island. The spines of this species are distinguishable by their large size and longitudinal striations. Some of the spines found are 20 millimeters long and 3 millimeters in diameter.

Locality.—San Pedro, Cal.

Geologic horizon.—San Pedro formation (lower part), Pleistocene.

Collection.—Leland Stanford Junior University.

STRONGYLOCENTROTUS PURPURATUS (Stimpson).

Strongylocentrotus purpuratus Arnold, 1903, California Acad. Sci. Mem., vol. 3, pp. 90, 91.
Strongylocentrotus purpuratus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 707.

Description.—Arnold, who mentions the discovery of spines of this species in the California Pleistocene, says:

> Numerous spines of this small purple sea urchin have been found in the San Pedro series. No part of the test has ever been discovered in these deposits, to the writer's knowledge. Several nearly perfect tests of this species were found in the Pleistocene (lower San Pedro series) deposits at the bathhouse, Santa Barbara. A nearly perfect test was also found in the upper horizon of the San Diego formation (Pleistocene (?)) at Pacific Beach, near San Diego.

Localities.—San Pedro, Santa Barbara, and San Diego, Cal.

Geologic horizon.—San Diego formation (upper part), Pliocene; San Pedro formation (lower part), Pleistocene.

Collection.—Leland Stanford Junior University.

Subclass IRREGULARIA.

Order GNATHOSTOMATA.

Suborder CLYPEASTRINA.

Family SCUTELLIDÆ.

DENDRASTER EXCENTRICUS (Eschscholtz).

Plate CIV, figures 1a–d; Plate CV, figures 1a–d.

Scutella striatula De Serres, 1829, Géognosie terr. tert. du midi de France, p. 156.
Scutella excentrica Eschscholtz, 1831, Zool. atlas, p. 19, Pl. XX, figs. 2, 2a, 2b.
Echinarachnius excentricus Valenciennes, 1846, Voyage Vénus, Zooph., Pl. X.
Dendraster excentricus L. Agassiz, 1847, Cat. raisonné des échinodermes, Soc. Nat. Ann., vol. 7, p. 135.
Dendraster excentricus Gray, 1855, Cat. Recent échinoderms, p. 16.
Dendraster excentricus Stimpson, 1857, Boston Soc. Nat. Hist. Jour., vol. 6, pp. 526–527.

Scutella striatula Conrad, 1857, U. S. Pacific R. R. Expl. 32d Par. and California, vol. 7, pl. IX, figs. 1a, 1b; non *Dendraster excentricus* Dujardin and Hupé, 1862, Hist. nat. zoophytes échinodermes, p. 564.
Scutella striatula Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Scutella striatula Gabb, 1869, California Geol. Survey, Paleontology, vol. 2, p. 110.
Scutella (Echinarachnius) excentricus A. Agassiz, 1872, Revision of the echini, Mus. Comp. Zoology Illus. Cat. No. 7, pp. 107, 524–526. Pl. XIIIa, figs. 1 to 4.
Echinarachnius excentricus Cooper, 1888, Cat. California fossils: State Mineralogist Seventh Rept., p. 271.
Echinarachnius excentricus Gregory, 1891, Geol. Soc. America Bull., vol. 3, p. 107.
Echinarachnius excentricus Merriam, 1899, California Acad. Sci. Proc., 3d ser., Geology, vol. 1, No. 5, p. 170, Pl. XXII, fig. 8.
Scutella (Echinarachnius) excentricus Arnold, 1903, California Acad. Sci. Mem., vol. 3, p. 91.
(?) *Echinarachnius excentricus* Eschscholtz var. Arnold, 1907, U. S. Geol. Survey Bull. 322, Pl. XXIV, fig. 8. (This is probably a variant form of *Dendraster gibbsii*.)
Scutella striatula Schuchert, 1908, U. S. Nat. Mus. Bull. 53, pt. 1, p. 594.
Echinarachnius excentricus Pack, 1909, California Univ. Dept. Geology Bull., vol. 5, No. 13, pp. 231–282.
Dendraster excentricus Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 707.

Determinative characters.—Test medium to large; subcircular to broadly subovate in marginal outline, broader posteriorly than anteriorly; upper surface greatly depressed around the margin, more or less tumid centrally; margin thin; under surface flat. Apex central or subcentral. Apical system excentric posteriorly; from one-fourth to one-third the radius from the center. Ambulacral petals large; posterior pair shorter than the others, less divergent, equally divergent, or slightly more divergent than the anterior pair. Peristome small, circular, central or subcentral; ambulacral furrows fork near the peristome, the branches at first diverging then converging slightly, each giving off one important and many small branches on the way to the margin. The stronger branches continue abactinally, but they are rarely discernible on fossil specimens. Periproct very small, circular or subelliptical, inframarginal.

Dimensions.—Specimen A: Length 83 millimeters; width 83 millimeters; height 12 millimeters. Specimen B: Length 97 millimeters; width 105 millimeters; height 19 millimeters.

Description.—This well-known Recent form, abundant on the Pacific coast, is so fully described in other works, that it is necessary to give here only the special points of interest in regard to the fossil specimens. Most of these have already been given in the determinative characters, but a few additional details will be presented. The size varies from less than 2 to more than 4 inches in diameter and less than one-fourth to about 1 inch in height. In marginal outline the smaller forms are usually subcircular while the large ones are usually broadly subovate and broader than long. The apex is usually between the center and the apical system, but is sometimes central or slightly excentric anteriorly. The area between the ends of the petals and the margin is wider than in forms which resemble this. The under surface is flat or slightly concave.

The ambulacral areas are wide, widest at the margin, where they are wider than the interambulacral areas; dorsal portions petaloid, the petals somewhat variable in details. The petals are large, the anterior three longer than the posterior pair, the odd petal longer than the anterior paired petals, though sometimes appearing of equal length or shorter by reason of the shortening of the distance between the pairs of pores of the poriferous zones for a greater or less distance from the end of the petal. The anterior paired petals are straight or nearly so and more widely divergent or equally divergent or slightly less divergent than the posterior pair. The posterior pair is usually less widely divergent and the poriferous zones of each petal are less widely divergent than in similar forms. The interporiferous areas of all the petals are rather wide and somewhat tumid.

The apical system is excentric posteriorly, being situated from one-fourth to one-third the distance from the center to the posterior margin; the madreporite is large and substellate with four genital pores at the anterior points of the star, the two anterior nearer together than the two posterior. There are also five small radial plates each perforated by a minute pore.

The peristome is central or slightly excentric posteriorly. The ambulacral furrows are simple and straight for a very short distance from the peristome, then fork nearly symmetrically into

two strong furrows which diverge for a short distance then converge slightly and continue nearly to the margin, giving off one large and many small branches on the way. Near the margin the large furrows split up into many small ones which on well-preserved fossil specimens and in recent specimens can be seen to continue over the margin and on the upper surface for a considerable distance.

The periproct is very small, usually circular, but sometimes subelliptical by longitudinal elongation; situated from 1 to 10 millimeters from the posterior border, being more distant in the large specimens.

Related forms.—*D. excentricus* is closely related to both *D. coalingaensis* and *D. gibbsii*. *D. coalingaensis* differs in being smaller, more uniformly depressed and therefore less tumid centrally, in having its apex more excentric posteriorly and more nearly coincident with the apical system and its periproct usually nearer the margin. The features in which *D. coalingaensis* resembles *D. excentricus* are so fundamental as to suggest that it is probably an ancestral form. *D. gibbsii* differs from *D. excentricus* in having its apex and apical system much more excentric posteriorly, its posterior ambulacral petals more widely divergent and with poriferous zones also diverging more widely from each other as well as differing more in length and its periproct usually nearer the posterior border. There do not appear to be any foreign forms closely related to the present species.

Localities.—San Diego (figured specimen A); Ventura County (figured specimen B); San Luis Obispo (Conrad's type); Riverside County; San Pedro (Cooper, Arnold), Santa Barbara (Gabb, Arnold); Seven Mile Beach, San Mateo County (Cooper); San Fernando, Los Angeles County (Cooper); all in California.

Geologic horizon.—San Pedro formation, Pleistocene.

Collections.—Wagner Free Institute of Science (2473, A); U. S. National Museum; Yale University; California Academy of Natural Sciences; Johns Hopkins University (T 2, B).

Genus MELLITA Agassiz.

Mellita pentapora (Gmelin).

Plate CVI, figure 1; Plate CVII, figures 1a-c.

Echinus pentaporus Gmelin, 1788, Linné, Systema naturæ, vol. 1, pt. 6, p. 3189.
Mellita testudinata Klein, 1734, Nat. disp. Echinodermata, p. 25, Pl. XXI, fig. C, D. (Copied in Enc. M., Pl. CXLIX, figs. 3, 4.)
Scutella quinquefora Lamarck, 1816, Animaux sans vertèbres, p. 9.
Scutella quinquefora Lamarck, 1840, Animaux sans vertèbres, 2d ed., p. 280.
Mellita testudinata Agassiz, 1841, Mon. échinodermes vivans et fossiles, Des scutelles, p. 40, Pl. IV, figs. 7–9.
Mellita quinquefora Agassiz, 1841, Mon. échinodermes vivans et fossiles, Des scutelles, p. 36, Pl. III.
Mellita ampla Holmes, 1847? MS.
Mellita ampla Ravenel, 1848, Echinidæ, recent and fossil, South Carolina, p. 2.
Mellita ampla Tuomey, 1848, Rept. Geology South Carolina, p. 205.
Mellita ampla Ravenel, 1850, Am. Assoc. Adv. Sci. Proc., vol. 3, p. 160.
Mellita ampla Michelin, 1855, Soc. géol. France Bull., 2d ser., vol. 12, p. 759.
Mellita texana Conrad, 1856, Acad. Nat. Sci. Philadelphia Proc., vol. 8, p. 316.
Mellita testudinata Desor, 1858, Synopsis des échinodermes fossiles, p. 237.
Mellita ampla Michelin, 1858, Rev. et mag. zool., 2d ser., vol. 10, pp. 362, 363, Pl. IX, fig. 1.
Mellita quinquefora var. *ampla* Holmes, 1860, Post-Pliocene fossils South Carolina, pp. 3, 4, Pl. I, fig. 6.
Mellita ampla, Dujardin and Hupé, 1862, Hist. nat. zoophytes échinodermes, p. 567.
Mellita pentapora Lütken, 1864, Bid. til Kunds. om Echinodermes, Vidensk. Medd. Kjøbenhavn.
Mellita texana Meek, 1864, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Mellita testudinata Agassiz, 1872, Revision of the Echini, pp. 141, 142.
Mellita testudinata Hilgard and Hopkins, 1878, Rept. Com. Engineers of Jan. 1875; suppl., pp. 23–33, 49, Pl. III, fig. 12.
Mellita pentapora Clark, 1902, U. S. Fish Com. Bull., p. 565, Pl. X.
Mellita ampla Stefanini, 1911, Soc. geol. italiana Boll., vol. 30, p. 708.

Determinative characters. Test medium to very large; subpentagonal in marginal outline, broadest opposite anterior paired petals; five long narrow lunules equal or subequal in length; margin thin, with a shallow notch at the anterior end; the whole form much depressed, the upper

surface rising gradually from the margin to the moderately elevated, anteriorly excentric apex; under surface flat. Ambulacral petals large, the posterior pair longer than the others. Apical system excentric anteriorly. Peristome small, subcircular, excentric anteriorly; ambulacral furrows simple and straight near the peristome, then forking, each pair of branches diverging and again converging near the margin. Periproct very small, elliptical, between the inner end of the odd lunule and the peristome.

Dimensions.—Figured specimen, one of the largest found: Length 152 millimeters; width 159 millimeters; height 19 millimeters. Smaller specimen: Length 106 millimeters; width 111 millimeters; height 12 millimeters.

Description.—The specimens herein described are believed to be representatives of the recent species *Mellita pentapora* (Gmelin) which has been known under the names of *M. testudinata* Klein and *M. quinquefora* Lamarck. Evidently, as Holmes recognized, the conditions were especially favorable to development along the South Carolina coast during Pleistocene time, a fact which is shown by the large size of the molluscan forms as well as by the Echinidæ.

As this well-known recent species is fully described in other works, it is necessary to give here only the special points of interest in regard to the specimens occurring as fossils. Conrad's species *Mellita texana*, of which what is probably the type is in the collection of the Academy of Natural Sciences of Philadelphia, presents no marked and constant points of difference from the recent species and therefore can not be recognized. Holmes's variety *ampla* is not entitled to separate recognition and description, as, aside from the unusual size of the South Carolina specimens, there are no decided and constant differences. Some specimens of the so-called variety *ampla* present differences in regard to the lunules which make them appear varietal in value, but a careful study of the large number of specimens in the collections of the United States National Museum and the Johns Hopkins University has demonstrated that the form of the lunules is so variable as to be unsafe as a feature for separation. This species is very abundant and occurs in a beautiful state of preservation at a few localities in South Carolina, but is rare elsewhere. Most of the important features of the test have been set forth in the determinative characters, but a few additional details will be given here. The size of the fossil forms from South Carolina is very great, ranging from 4 to 7 inches in diameter and from $\frac{1}{2}$ to $\frac{7}{8}$ inch in height, while those from Texas are rather small, being between 2 and 3 inches in diameter, which is about the same as that of the average recent forms. The test is usually slightly broader than long. The margin is truncated and especially thin posteriorly. The lunules are long narrow slits of about the same width from end to end, bluntly rounded at the ends, the length and width quite variable even on the same specimen, the odd posterior lunule usually wider and of equal length or slightly longer or shorter than the rest; the average length in the South Carolina forms is about 1 inch and the width one-eighth of an inch. The petaloid region is large; the petals are long and wide, subelliptical to subspatulate in form, extending about halfway to the margin, well open at their ends, with very broad poriferous zones which about equal in width the interporiferous areas. The apical system is large; madreporite large and stellate; four genital pores at the tips of the points of the star, the two posterior farthest apart; five small pores at inner ends of reentrant angles of the star. The main branches of the ambulacral furrows are more or less flexuous and each branch gives off one important lateral branch as it bends to approach the margin. The undersurface, though flat in general, has shallow grooves along the middle of each ambulacrum.

Related forms.—The only American fossil form which is closely related to the present species is *Mellita caroliniana* which, however, is readily distinguished by its having a sixth lunule in the middle of the anterior ambulacrum, by having its ambulacral lunules nearer the margin and its posterior paired lunules longer than the anterior pair; and having the relative height of its test less than in *M. pentapora*.

Localities.—Simmons Bluff, Youngs Island, Wadmalaw Sound, S. C.; Brunswick Canal, Glynn County, Ga.; Texas (?).

Geologic horizon.—Pleistocene.

Collections.—Johns Hopkins University (T 2, T 4); American Museum of Natural History; U. S. National Museum; Wagner Free Institute of Science; Academy of Natural Sciences of Philadelphia.

Order ATELOSTOMATA.

Suborder STERNATA.

Family SPATANGIDÆ.

Genus SCHIZASTER Agassiz.

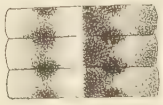
SCHIZASTER ATROPOS (Lamarck).

Schizaster atropos Ravenel, 1848, Echinidæ, recent and fossil, South Carolina, p. 4.
Schizas'er atropos Holmes, 1858, Post-Pliocene fossils South Carolina, pp. 5, 6, Pl. II, fig. 3.
Mœra lachesis Desor, 1858, Synopsis échinides fossiles, p. 394.
Schizaster atropos A. Agassiz, 1874, Revision of the Echini, p. 751.

Description.—No material has been found that can be referred to this species.
Locality.—Abbapoola Creek, Johns Island, S. C. (Holmes).
Geologic horizon.—Pleistocene.
Collection.—Unknown.

PLATES.

398000 15 16

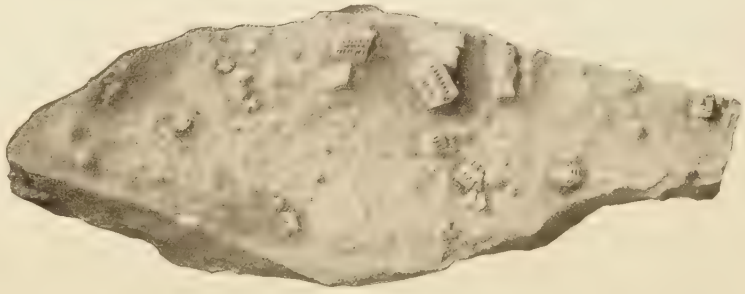


2b

1a

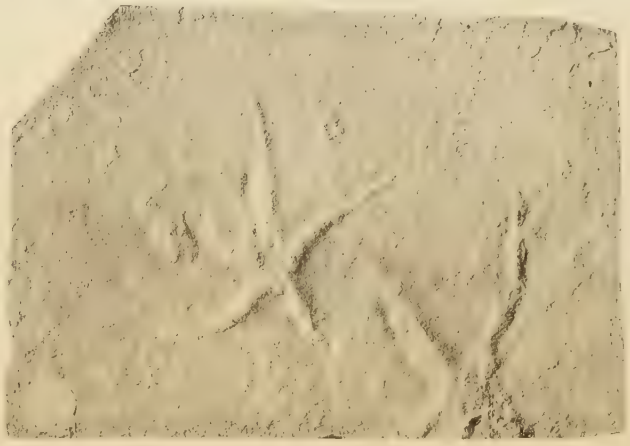
1b

2a



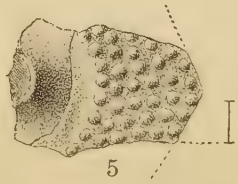
2c

3a



4

3b



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6

TRIASSIC CRINOIDEA AND ECHINOIDEA.

PLATE I.

ISOCRINUS SMITHI Clark, n. sp. (p. 21).

U. S. Nat. Mus. 31184, type.

FIGURE 1a. Articular surface of a detached joint of the column, × 4.
1b. Lateral view of a detached joint of the column, × 4.

ISOCRINUS CALIFORNICUS Clark, n. sp. (p. 21).

U. S. Nat. Mus. 31185, type.

FIGURE 2a. Articular surface of a detached joint of the column, × 6.
2b. Lateral view of a portion of the column, × 6.
2c. Several specimens of column joints.

ENCRINUS HYATTI Clark, n. sp. (p. 22).

U. S. Nat. Mus. 31186, type.

FIGURE 3a. Articular surface of a detached joint of the column, × 1¾.
3b. Lateral view of a portion of the column, × 1¾.

ASPIDURA (?) IDAHOENSIS Clark, n. sp. (p. 23).

U. S. Nat. Mus. 31187, type.

FIGURE 4. Cast of two specimens.

CIDARIS SHASTENSIS Clark, n. sp. (p. 23).

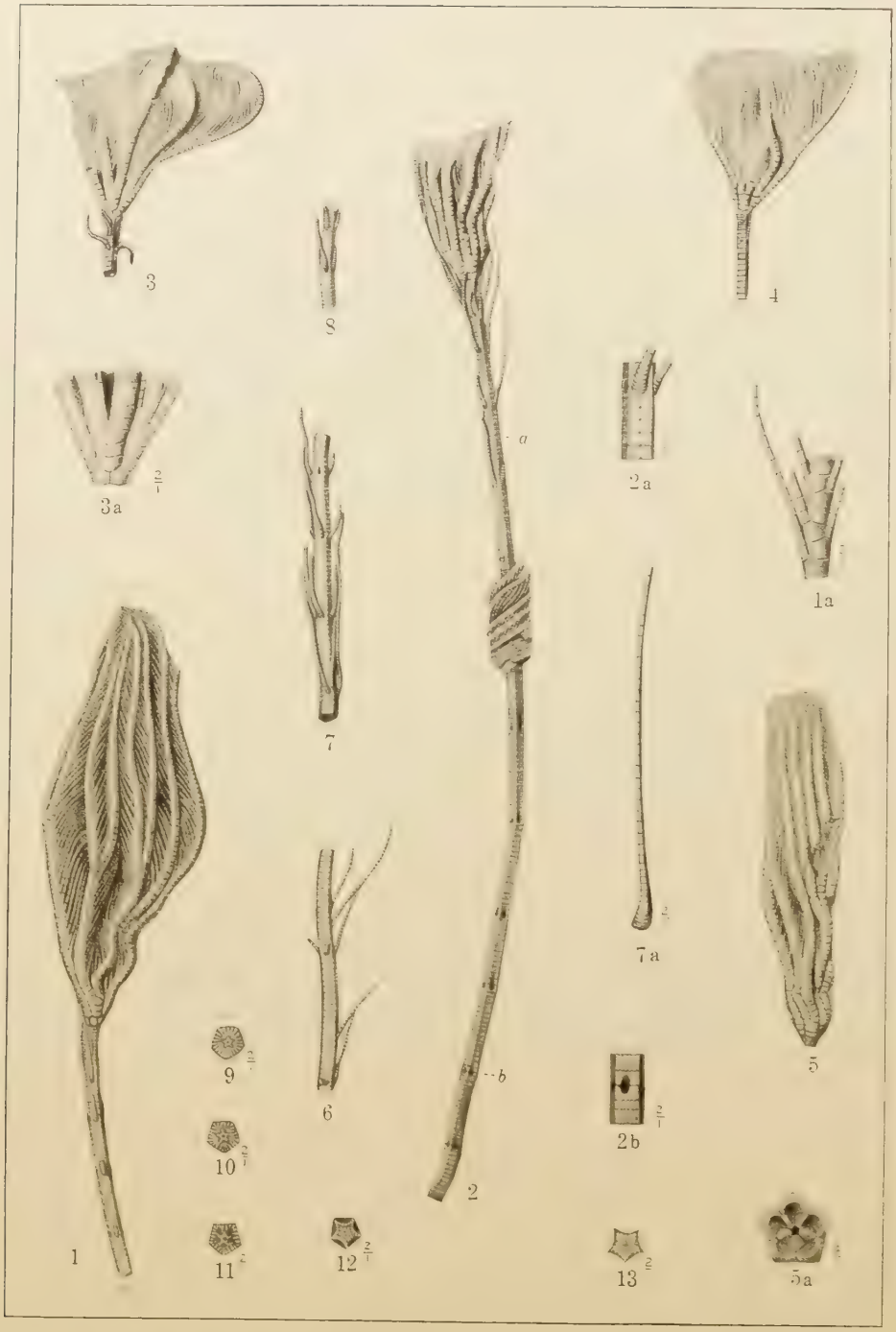
U. S. Nat. Mus. 31188, type.

FIGURE 5. Fragment of interambulacral plate, × 3.

CIDARIS DILLERI Clark, n. sp. (p. 23).

U. S. Nat. Mus. 31189, type.

FIGURE 6. Portion of test.



JURASSIC CRINOIDEA.

PLATE II.

ISOCRINUS KNIGHTI Springer (p. 25).

U. S. Nat. Mus. Springer A–H, type. (After Springer.)

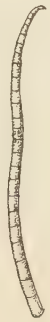
FIGURE 1. Large specimen A; with bifurcating arms complete and part of stem; cirri mostly lost.
1a. Syzygy at IIIBr 79+80 of same specimen.
2. Large specimen, B, with stem 140 millimeters, and part of arms. Some arms of another individual attached.
2a. Detail of stem at "a" of same specimen, showing interarticular pores, × 2.
2b. Detail of same at "b", showing cirrus sockets, × 2.
3. Small specimen, C, with part of arms, some not bifurcating.
3a. Calyx and lower IIIBr of same specimen, showing form and proportions of basal and radial plates, × 2.
4. Small specimen, D, with part of arms, one with an axillary, and some apparently simple.
5. Small specimen, E, with two arms simple and one bifurcating at 23d IIIBr, stem detached, exposing infrabasals.
5a. Basal view of same specimen, showing infrabasals, × 4.
6–8. Portions of different stems, F, G, H, showing cirri.
7a. The longest cirrus on specimen G, × 2.
9–13. Weathered stem joints associated with the other specimens: 9, 10, 11 are mature internodals; 12 is the proximal face of a nodal incised by three cirrus sockets; 13 is a deeply stellate joint from the youngest part of the stem; all × 2.

4

1a

1b

1c



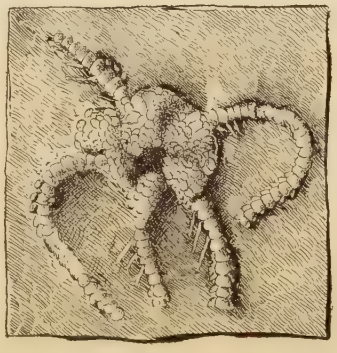
1d

2

3a

3b

3c



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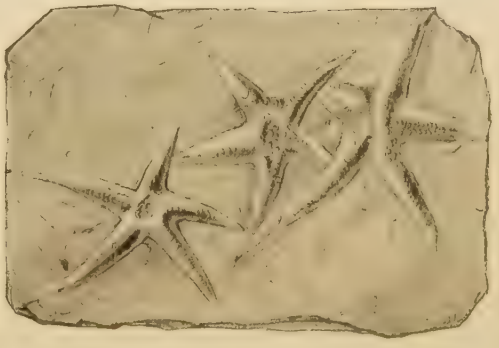


6

JURASSIC CRINOIDEA AND STELLEROIDEA.

PLATE III.

Isocrinus knighti Springer (p. 25).

U. S. Nat. Mus. 682.

Figure 1a. Column with attached pinnules.
1b. Articular surface of a detached joint of the column, × 4.
1c. Lateral view of a portion of the column, × 4.
1d. Enlarged pinnule, × 2.

Pentacrinus asteriscus Meek and Hayden (p. 26).

U. S. Nat. Mus. 220, type. (After Meek and Hayden.)

Figure 2. Upper surface of a detached joint, × 5.

Pentacrinus whitei Clark (p. 27).

U. S. Nat. Mus. 8588, type.

Figure 3a. Articular surface of a detached joint of the column, × 2.
3b. Same, × 2.
3c. Lateral view of a portion of the column.

Pentacrinus shastensis Clark, n. sp. (p. 28).

U. S. Nat. Mus. 31180, type.

Figure 4. Articular surface of a detached joint of the column, × 3.

Ophioglypha utahensis Clark, n. sp. (p. 29).

U. S. Nat. Mus. 22839, type.

Figure 5. Upper surface of specimen, × 3.

Asterias (?) dubium Whitfield (p. 28).

U. S. Nat. Mus. 12325, type.

Figure 6. Gutta-percha cast of three individuals.

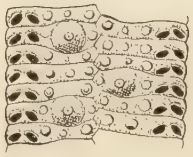
1b

1a

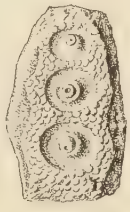
1c

2a

2b



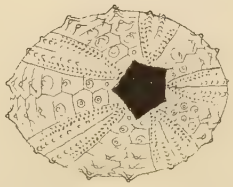
4g



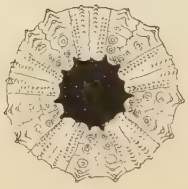
3

4f

4i



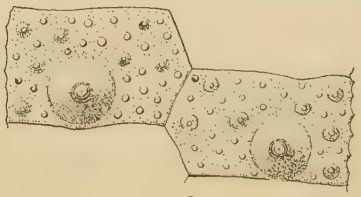
4a



4b

4c

4h



4d

4e

JURASSIC ECHINOIDEA.

PLATE IV.

Cidaris californicus Clark (p. 30).

U. S. Nat. Mus. 30184, type.

Figure 1a. Spine.
1b. Same.
1c. Articular surface of 1b, × 2.

Cidaris taylorensis Clark (p. 30).

U. S. Nat. Mus. 30183, type.

Figure 2a. Fragment containing two contiguous interambulacral plates of the same series.
2b. Spine.

Cidaris plumasensis Clark, n. sp. (p. 31).

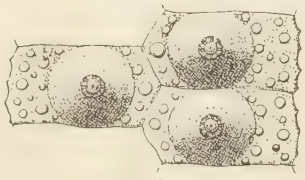
U. S. Nat. Mus. 31191, type.

Figure 3. Portion of interambulacral area.

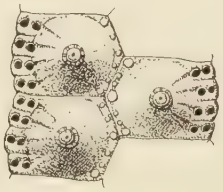
Hemicidaris intumescens Clark (p. 31).

U. S. Nat. Mus. 30187 and 30188, types.

Figure 4a. Upper surface of the test. Partly restored.
4b. Lower surface of the test. Partly restored.
4c. Lateral view of the same. Partly restored.
4d. Two interambulacral plates, × 5.
4e. Lower portion of interambulacrum, × 5.
4f. Upper portion of the same, × 5.
4g. Portion of ambulacrum, × 4.
4h. Tubercle from above, × 8.
4i. Lateral view of the same, × 8.

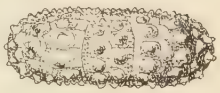


1b



1c

1d



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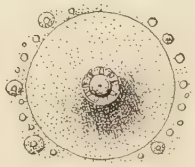
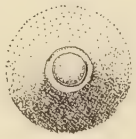


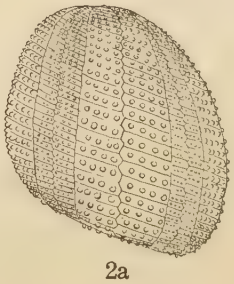
1e

2e



2d

2b



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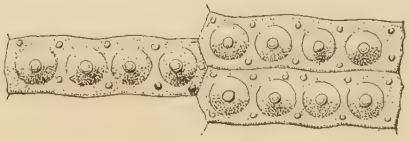


2c

3a

4

3b

JURASSIC ECHINOIDEA.

PLATE V.

Pseudodiadema emersoni Clark (p. 32).

U. S. Nat. Mus. 30186, type.

Figure 1a. Lateral surface of the test.
1b. Portion of interambulacrum, × 3.
1c. Portion of ambulacrum, × 3.
1d. Tubercle from the side, × 5.
1e. The same from above, × 5.

Stomechinus hyatti Clark (p. 33).

U. S. Nat. Mus. 30185, type.

Figure 2a. Lateral surface of the test, slightly distorted.
2b. Portion of ambulacrum, × 4.
2c. Portion of interambulacrum, × 4.
2d. Tubercle from above, × 8.
2e. The same from the side, × 8.

Holectypus pealei Clark, n. sp. (p. 33).

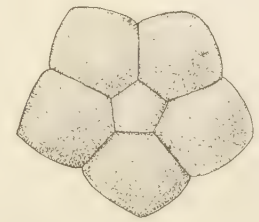
U. S. Nat. Mus. 31192, type.

Figure 3a. Lateral surface of the test.
3b. Upper surface of the test.

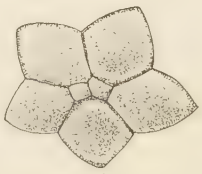
Holectypus cragini Clark, n. sp. (p. 34).

U. S. Nat. Mus. 31193, type.

Figure 4. Upper surface of the test.

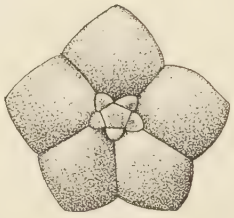


3a



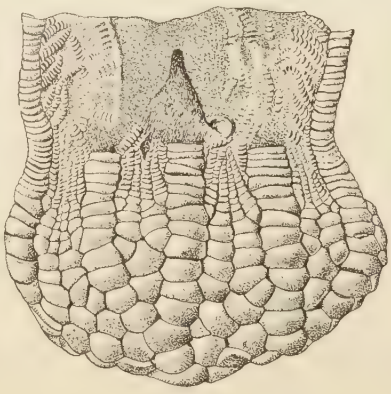
3b

3c

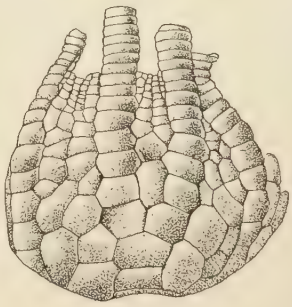


3d

3h



3g

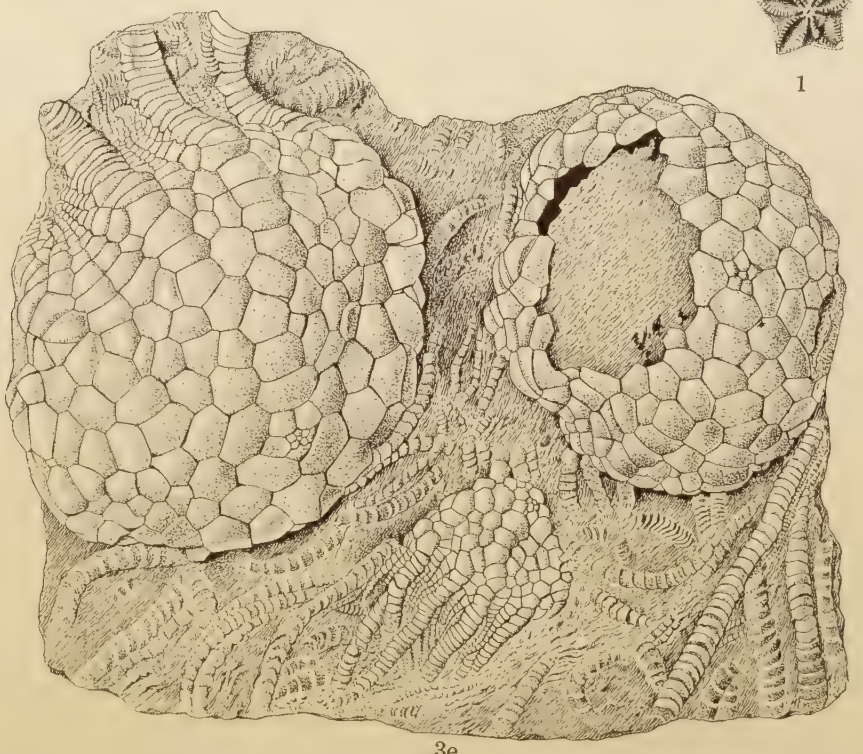


3f

2a

2b

1



3e

CRETACEOUS CRINOIDEA.

PLATE VI.

Pentacrinus tehamaensis Clark, n. sp. (p. 35).

U. S. Nat. Mus. 31194, type.

Figure 1. Articular surface of a detached joint of the column, × 2.

Pentacrinus bryani Gabb (p. 35).

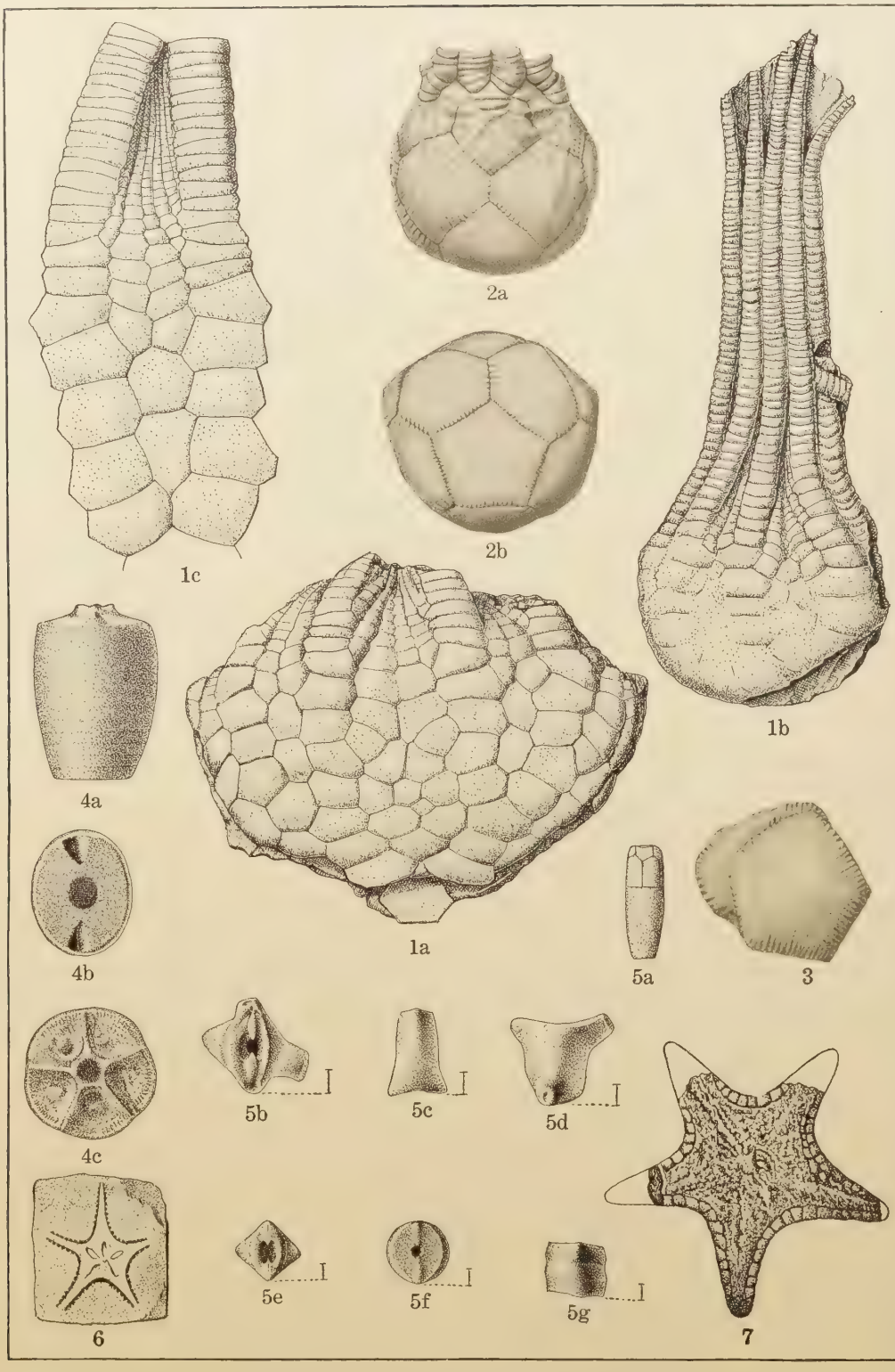
Acad. Nat. Sci. Philadelphia 1458, type.

Figure 2a. Lateral view of a portion of a joint column.
2b. Articular surface of the column.

Uintacrinus socialis Grinnell (p. 36).

Mus. Comp. Zoology, Cambridge. (Figures after Springer.)

Figure 3a. Monocyclic; regular; centrale of maximum size.
3b. Monocyclic; irregular; double centrale.
3c. Dicyclic; irregular; double centrale and 1 IB.
3d. Dicyclic; regular; IBB fully developed.
3e. Specimen, with three individuals, showing dicyclic and monocyclic forms of base, and maximum and small size, lying together in close contact on the slab; the black membrane lining the calyx is also shown at the edge of the broken plates.
3f. *Uintacrinus westfalicus* Schlueter. Figure of the type specimen for comparison (after Schlueter).
3g. Specimen laterally compressed; showing the fixed and proximal free pinnules, and the anal tube in natural position.
3h. Articulating surfaces of brachials, enlarged × 2.2; to show the diagonal direction of the fulcral ridges.



CRETACEOUS CRINOIDEA AND STELLEROIDEA.

PLATE VII.

UINTACRINUS SOCIALIS Grinnell (p. 36).

U. S. Nat. Mus. 8044.

FIGURE 1a. Lateral view of the test.
1b. Test showing pinules.
1c. Part of test, × 2.

MARSUPITES AMERICANUS Springer (p. 39).

FIGURE 2a. Side of calyx, with bases of arms, and a strong interbrachial passing in between them.
2b. Base of the same.
Collection of Frederick Brawn.
3. Infrabasal plate of much larger specimen.
Collection of Frank Springer.

RHIZOCRINUS ALABAMENSIS (De Loriol) (p. 39).

Cincinnati Soc. Nat. Hist., type.

FIGURE 4a. Side of the basal cone.
4b. Upper surface of the same.
4c. Lower surface of the same.

RHIZOCRINUS CYLINDRICUS Weller (p. 40).

New Jersey Geol. Survey, type.

FIGURE 5a. Lateral view of a complete body, × 2.
5b-g. Various sides of several column joints, probably belonging to this species (enlarged). Johns Hopkins Univ.

ASTROPECTEN (?) MONTANUS Douglas (p. 41).

Carnegie Mus. 601, type.

FIGURE 6. Impression of skeleton.

PENTAGONASTER BROWNI Weller (p. 41).

Walker Mus., Chicago, type.

FIGURE 7. Dorsal surface (?).

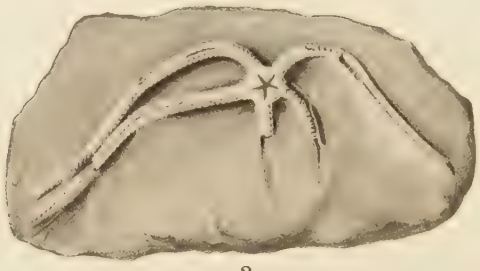
1a

1b

1c

1d

1e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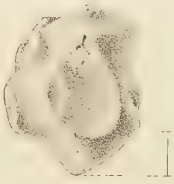
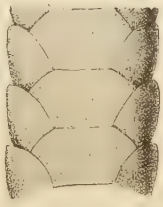
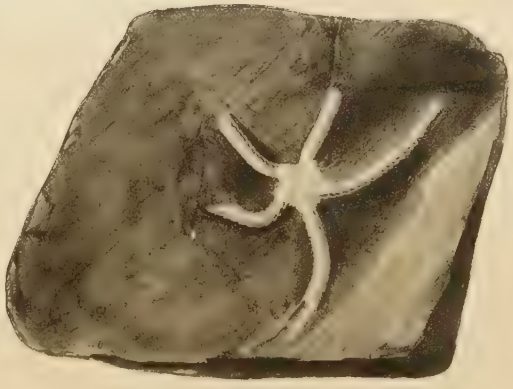

2a

2b

3c


3b

4b


4a

1f

1g

1h

CRETACEOUS STELLEROIDEA.

PLATE VIII.

GONIASTER MAMMILLATA Gabb (p. 42).

Acad. Nat. Sci. Philadelphia 1457, type.

FIGURE 1a–g. Various sides of four different plates, × 2.
1h. Surface of plate, × 20.

PENTACEROS ASPERULUS Clark (p. 42).

Johns Hopkins Univ. T 3014, type.

FIGURE 2a. Top of plate.
2b. Side of plate.

OPHIOGLYPHA TEXANA Clark (p. 43).

U. S. Nat. Mus. 21884, type.

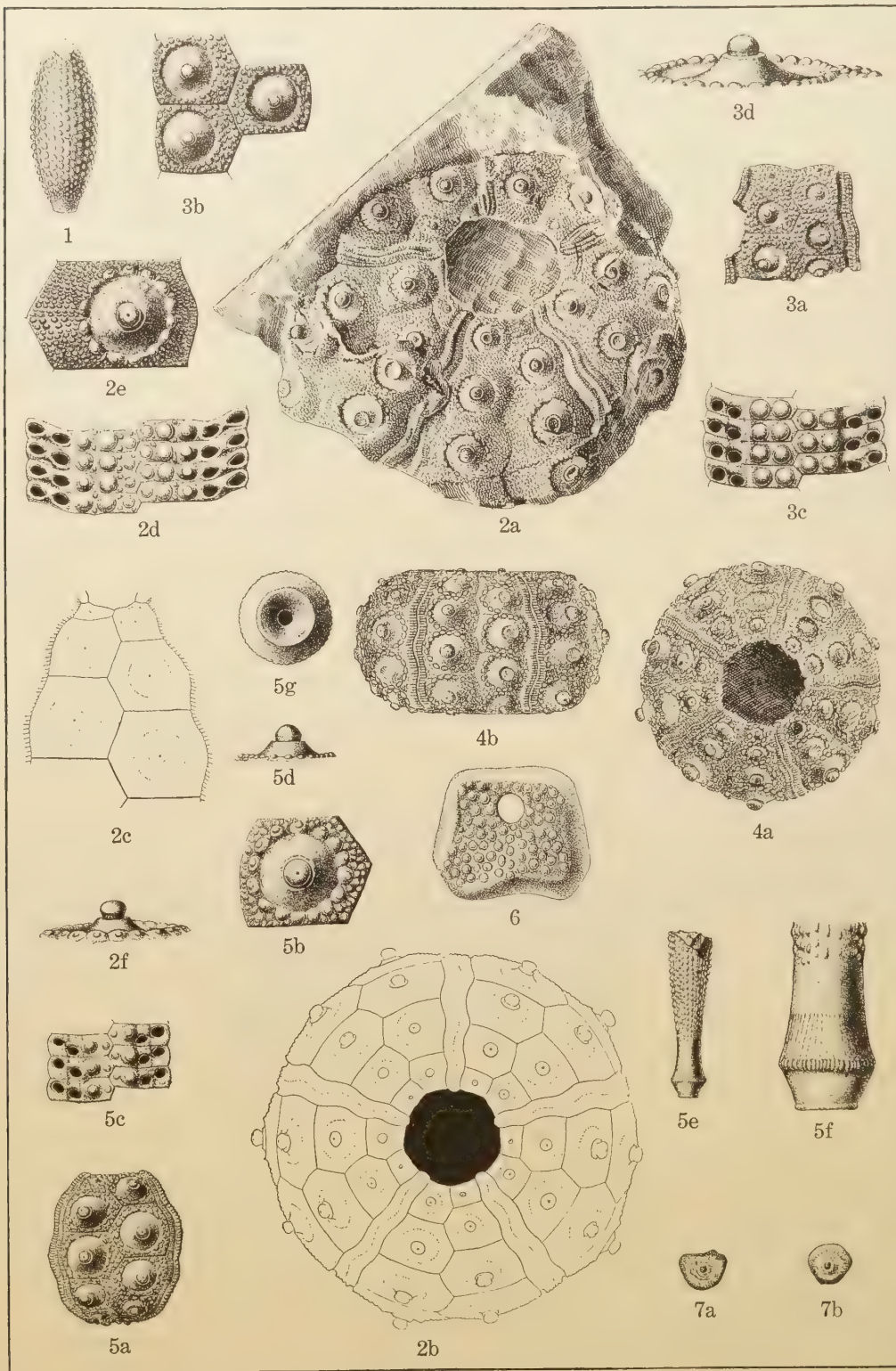
FIGURE 3a. Oral surface.
3b. Portion of aboral surface, × 5.
3c. Portion of oral surface, × 5.

OPHIOGLYPHA BRIDGERENSIS (Meek) (p. 43).

U. S. Nat. Mus. 7820, type.

FIGURE 4a. Skeleton, natural size.
4b. Portion of the upper surface.

39800 15 17



CRETACEOUS ECHINOIDEA.

PLATE IX.

Cidaris tehamaensis Clark, n. sp. (p. 44).

U. S. Nat. Mus. 31195, type.

Figure 1. Lateral view of spine.

Cidaris texanus Clark (p. 45).

U. S. Nat. Mus. 8381, type.

Figure 2a. Test, natural size.
2b. Test, restored, slightly enlarged.
2c. Arrangement of the interambulacral plates in the vicinity of the apical disk, with adjacent ambulacral plates. Slightly enlarged.
2d. Portion of ambulacrum, × 6.
2e. Interambulacral plate, slightly enlarged.
2f. Tubercle, × 3.

Cidaris walcotti Clark (p. 45).

Acad. Nat. Sci. Philadelphia 1451, type.

Figure 3a. Portion of the test.
3b. Interambulacral plates, × 2.
3c. Portion of ambulacrum, × 8.
3d. Tubercle, × 4.

Cidaris splendens Morton (p. 46).

Johns Hopkins Univ. T 3001.

Figure 4a. Upper surface of the test.
4b. Lateral surface of the test.

Cidaris splendens Morton (p. 46).

Acad. Nat. Sci. Philadelphia, type.

Figure 5a. Portion of test.
5b. Interambulacral plate, × 2.
5c. Portion of ambulacral area, × 5.
5d. Tubercle, lateral view, × 2.
5e. Spine, × 2.
5f. Base of same, × 6.

Cidaris splendens Morton (p. 46).

Johns Hopkins Univ. T 3002.

Figure 6. Genital plate.

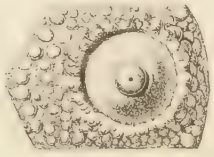
Cidaris dixiensis Clark, n. sp. (p. 47).

Geol. Survey Texas, type.

Figure 7a. Interambulacral plate.
7b. Same.

1e

1f



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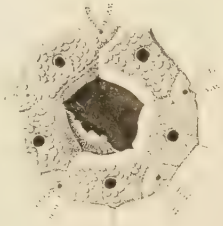


1g

1c

1a

1b

CRETACEOUS ECHINOIDEA.

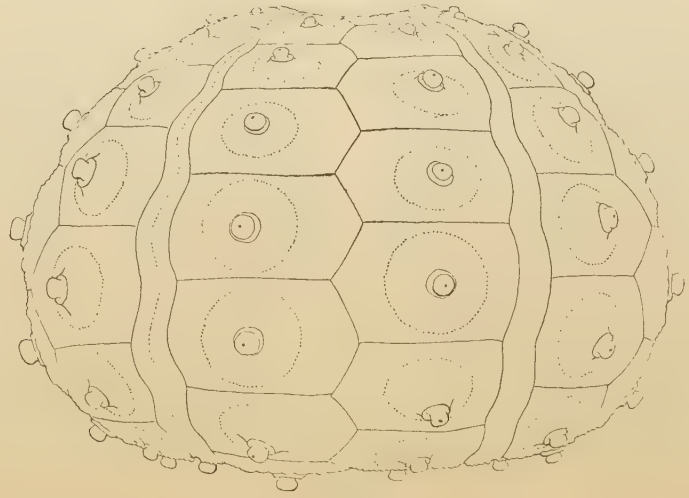
PLATE X.

LEIOCIDARIS HEMIGRANOSUS (Shumard) (p. 48).

U. S. Nat. Mus. 21768.

FIGURE. 1a. Upper surface of the test, × ¾.
1b. Lower surface of the test, × ¾.
1c. Lateral surface of the test, × ¾.
1d. Interambulacral plate.
1e. Portion of ambulacrum, × 5.
1f. Tubercles, × 2.
1g. Apical system.

1a



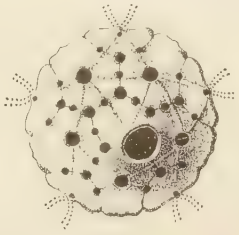
1b

PLATE XI.

LEIOCIDARIS HEMIGRANOSUS (Shumard) (p. 48).

U. S. Nat. Mus. 21768.

FIGURE 1a. Upper surface of the test restored, natural size.
1b. Lateral view of the same.



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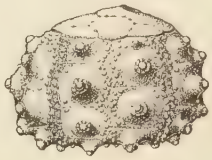
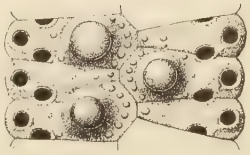


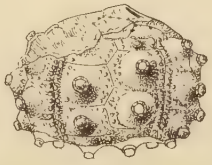
1d



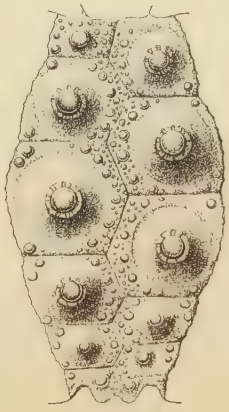
1g

1h

1f



1a



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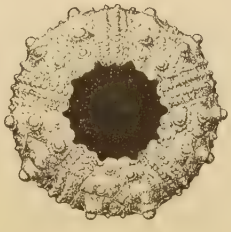

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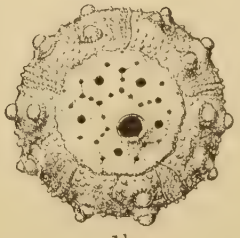


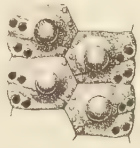
1b

PLATE XII.

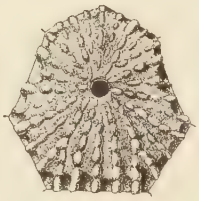
SALENIA TEXANA Credner (p. 49).

U. S. Nat. Mus. 8329, specimen A.

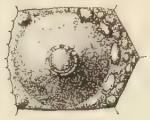
FIGURE 1a. Lateral view of the test slightly enlarged.
1b. Upper surface of the test restored, slightly enlarged.
1c. Lower surface of the same.
1d. Lateral surface of the same.
1e. Interambulacrum, × 3.
1f. Ambulacrum, × 4.
1g. Portion of the same, × 10.
1h. Tubercle.
1i. Apical system, × 1½.



1f



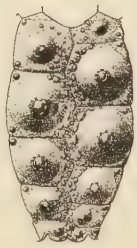
1h



1e

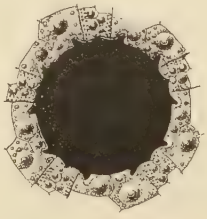
1g

1j



1d

1a



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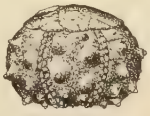
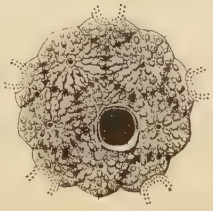


1c



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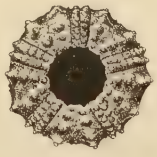

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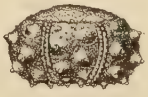
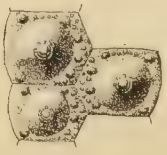


2c

2e



2d

2a

2g

2b

CRETACEOUS ECHINOIDEA.

PLATE XIII.

Salenia tumidula Clark (p. 50).

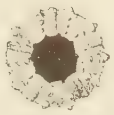
Acad. Nat. Sci. Philadelphia 1448, type.

Figure 1a. Upper surface of the test, × 2.
1b. Under surface of the test, × 2.
1c. Lateral surface of the test, × 2.
1d. Interambulacrum, × 5.
1e. Single plate of same, × 8.
1f. Portion of ambulacrum, × 10.
1g. Apical system, × 1½.
1h. Genital plate of same, × 6.
1i. Peristome, × 3.
1j. Tubercle, × 10.

Salenia bellula Clark (p. 51).

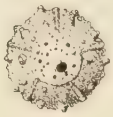
Acad. Nat. Sci. Philadelphia 1446, type.

Figure 2a. Upper surface of the test, × 2.
2b. Under surface of the test, × 2.
2c. Lateral surface of the test, × 2.
2d. Three interambulacral plates, × 6.
2e. Three ambulacral plates, × 10.
2f. Apical disk enlarged.
2g. Tubercle, × 10.

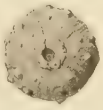


1b

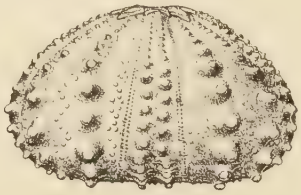
1c



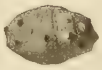
1a



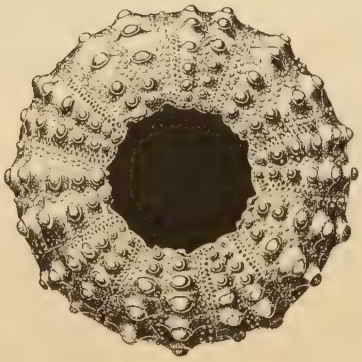
2a



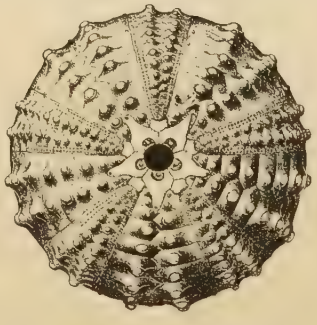
3c



2b



3b



3a

CRETACEOUS ECHINOIDEA.

PLATE XIV.

Salenia texana Credner (p. 49).

Johns Hopkins Univ. T 3003, specimen B.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.

Hypodiadema elegans Clark, n. sp. (p. 52).

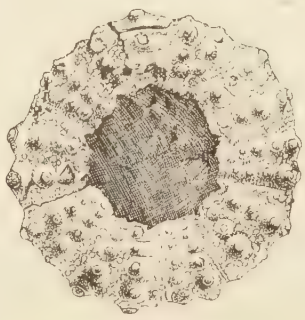
U. S. Nat. Mus. 31196, type.

Figure 2a. Upper surface of the test.
2b. Lateral surface of the test.

Goniopygus zitteli Clark (p. 52).

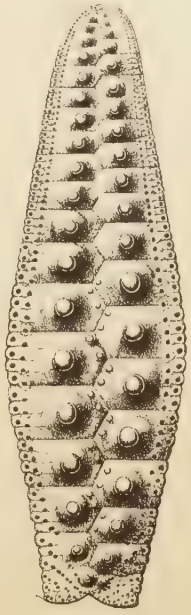
U. S. Nat. Mus. 12234, type.

Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.



1b

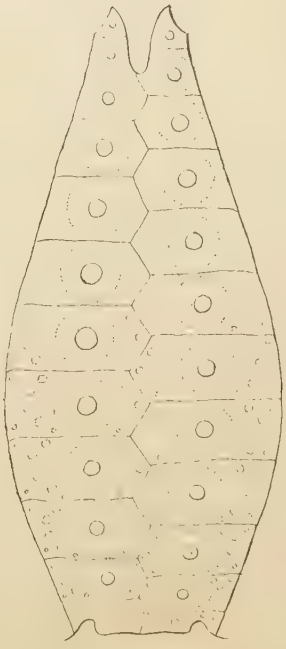
1a



1d

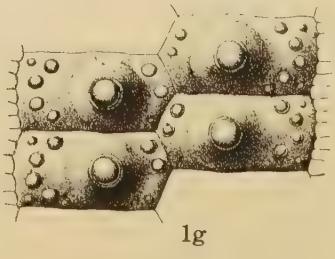
1f

1e



1c

1h



1g

CRETACEOUS ECHINOIDEA.

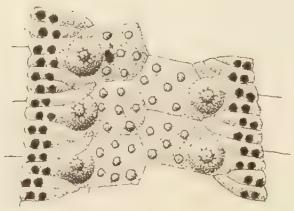
PLATE XV.

GONIOPYGUS ZITTELI Clark (p. 52).

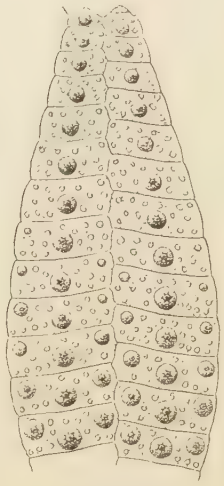
U. S. Nat. Mus. 12234, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the same.
1c. Interambulacrum, × 3.
1d. Ambulacrum, × 3.
1e. Side of tubercle, × 10.
1f. Apical system, × 4.
1g. Portion of interambulacrum, × 4.
1h. Lower portion of ambulacrum, × 10.

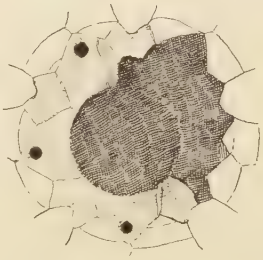
1d



1e

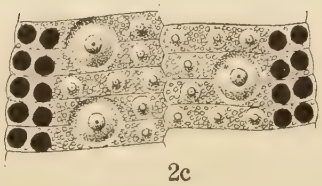


1f



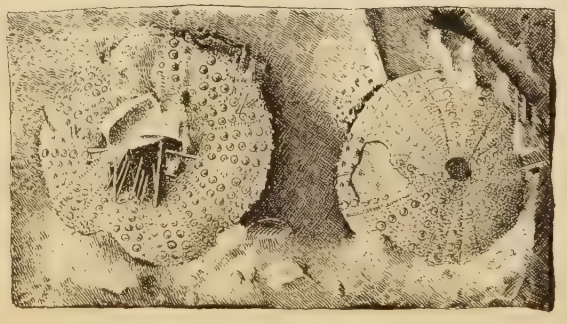
1c

1a



2c

1b



2a

2b

CRETACEOUS ECHINOIDEA.

PLATE XVI.

LEPTARBACIA ARGUTUS Clark, n. sp. (p. 53).

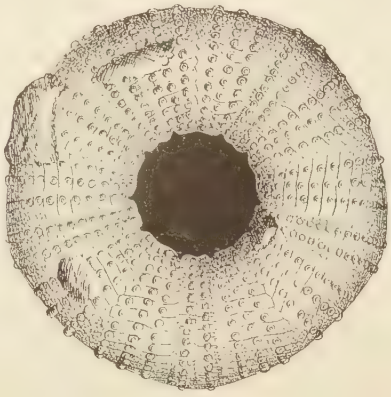
Johns Hopkins Univ. T 3004, type.

FIGURE 1a. Upper surface of the test.
1b. Lateral surface of the test.
1c. Apical system, × 8.
1d. Portion of ambulacrum, × 8.
1e. Portion of ambulacrum, × 15.
1f. Portion of interambulacrum, × 4.

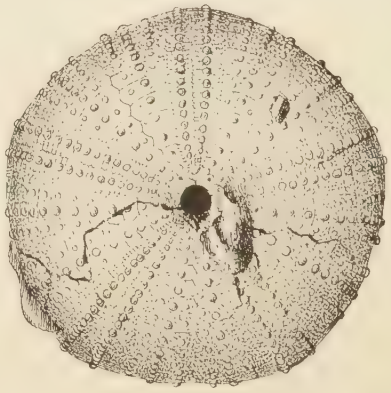
ORTHOPSIS PLANULATA Clark, n. sp. (p. 54).

Johns Hopkins Univ. 73005, type.

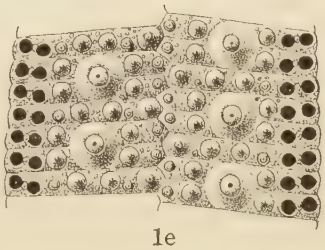
FIGURE 2a. Upper and lower surfaces of two forms.
2b. Lateral surface of the test.
2c. Portion of ambulacrum, × 6.



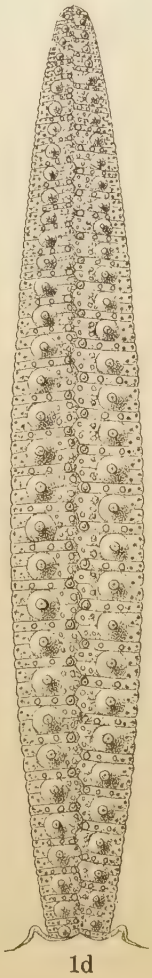
1b



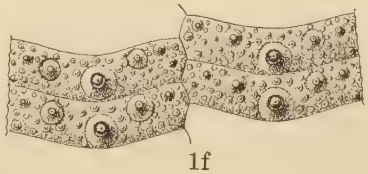
1a



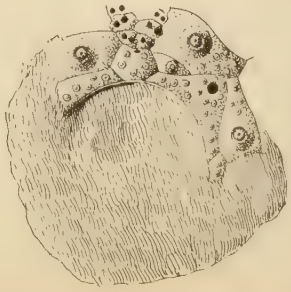
1e



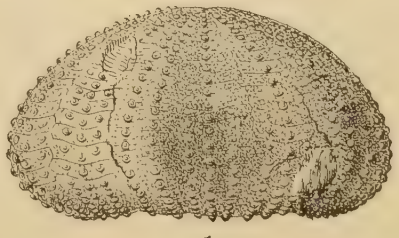
1d



1f



1g



1c

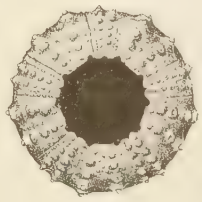
CRETACEOUS ECHINOIDEA.

PLATE XVII.

ORTHOPSIS OCCIDENTALIS Cragin (p. 54).

Geol. Survey Texas, type.

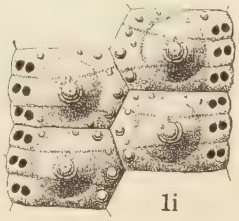
FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Ambulacrum, × 3.
1e. Portion of ambulacrum, × 6.
1f. Portion of interambulacrum, × 3.
1g. Portion of apical system, × 4.



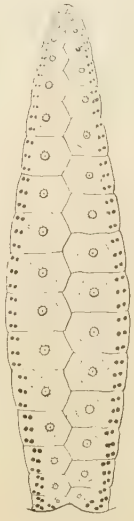
1b

1c

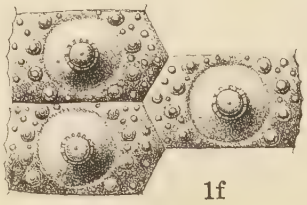
1a



1i



1e



1f

1d

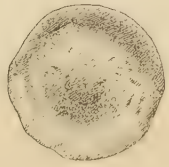
1g

1h

2c

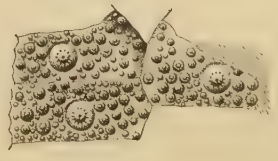
2a

2f



2b

2d



2e

PLATE XVIII.

Pseudodiadema texanum (Roemer) (p. 55).

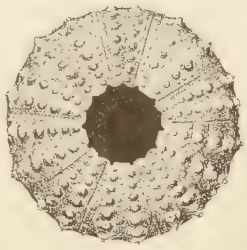
U. S. Nat. Mus. 31197.

Figure 1a. Upper surface of the test, × 2.
1b. Lower surface of the same, × 2.
1c. Lateral surface of the same, × 2.
1d. Interambulacrum, × 4.
1e. Ambulacrum, × 4.
1f. Three interambulacral plates, × 8.
1g. Tubercle, × 12.
1h. Portion of interambulacrum, × 8.
1i. Portion of ambulacrum, × 8.

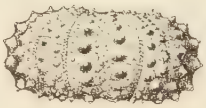
Heterodiadema ornatum Clark, n. sp. (p. 56).

Johns Hopkins Univ. T 3006, type.

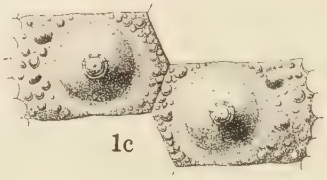
Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Portion of ambulacrum, × 10.
2e. Portion of interambulacrum, × 10.
2f. Lateral view of tubercle, × 20.



1a

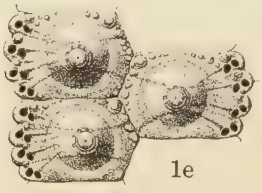


1b

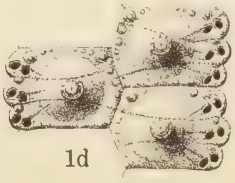


1c

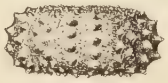
1f



1e

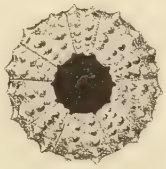


1d

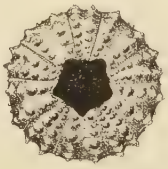


2c

2d

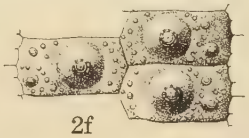


2b

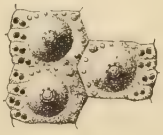


2a

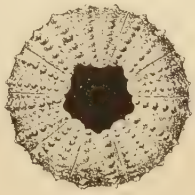
2g



2f

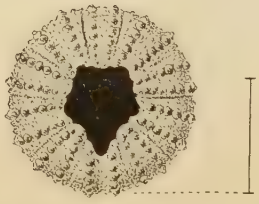


2e

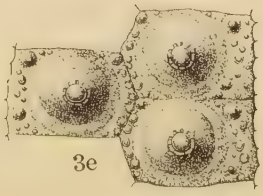


3b

3f

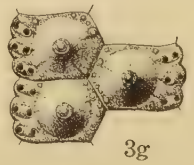


3a



3e

3d



3g

3c

3h

CRETACEOUS ECHINOIDEA.

PLATE XIX.

Pseudodiadema diatretum (Morton) (p. 56).

Acad. Nat. Sci. Philadelphia 1471, type.

Figure 1a. Lower surface of the test.
1b. Lateral view of the test.
1c. Two interambulacral plates, × 5.
1d. Three ambulacral plates, × 8.
1e. Same, × 8.
1f. Tubercle, × 8.

Cyphosoma hilli Clark (p. 59).

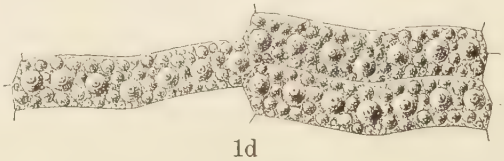
U. S. Nat. Mus. 8311, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Upper portion of an ambulacrum, × 5.
2e. Three plates of the same, × 8.
2f. Three interambulacral plates, × 4.
2g. Tubercle.

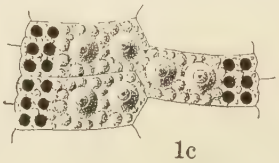
Coptosoma speciosum Clark (p. 61).

Acad. Nat. Sci. Philadelphia 1468, type.

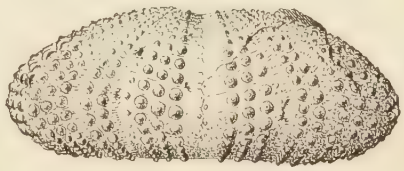
Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Upper portion of an interambulacrum, × 4.
3e. Three plates of the same, × 5.
3f. Three plates of ambulacrum, × 4.
3g. Same, × 4.
3h. Tubercle, × 10.



1d

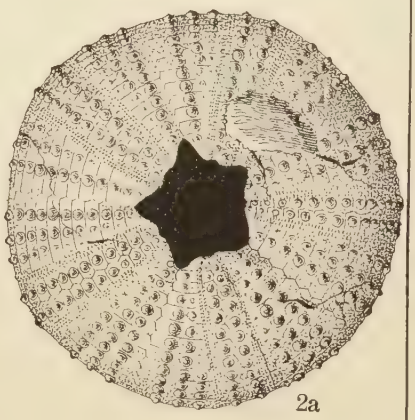


1c

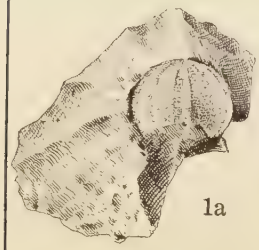


2c

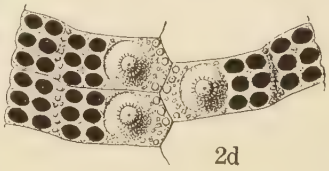
1b



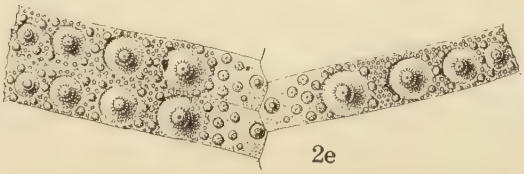
2a



1a

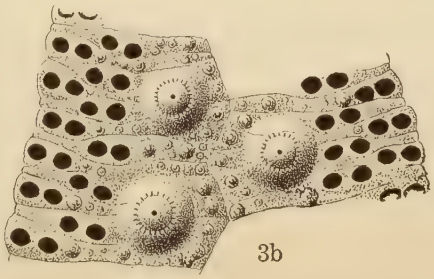


2d



2e

2b



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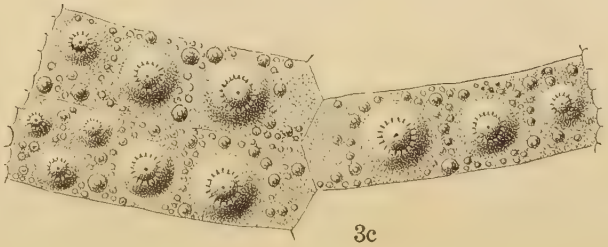


3c

3a

CRETACEOUS ECHINOIDEA.

PLATE XX.

Cottaldia rotula Clark, n. sp. (p. 57).

Johns Hopkins Univ. T 3007, type.

Figure 1a. Side of test of large specimen.
1b. Side of test of small specimen.
1c. Portion of ambulacrum, × 10.
1d. Portion of interambulacrum, × 10.

Diplopodia taffi Cragin (p. 58).

Geol. Survey Texas, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Portion of ambulacrum, × 5.
2e. Portion of interambulacrum, × 5.

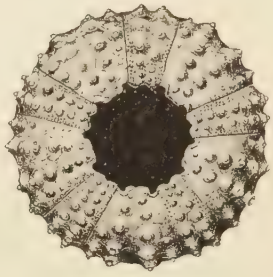
Diplopodia streeruvitzi Cragin (p. 58).

Geol. Survey Texas, type.

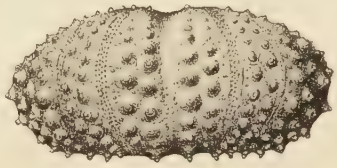
Figure 3a. Upper surface of the test.
3b. Portion of ambulacra, × 8.
3c. Portion of interambulacrum, × 8.

1a

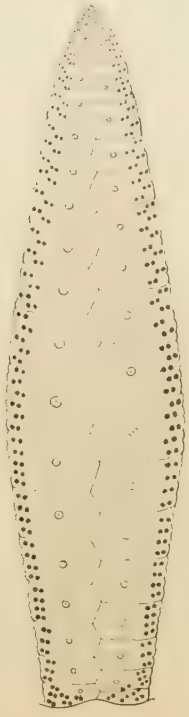
1d



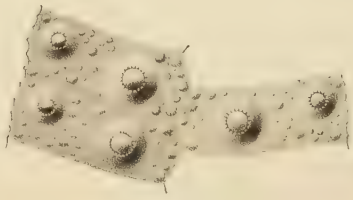
1b



1c



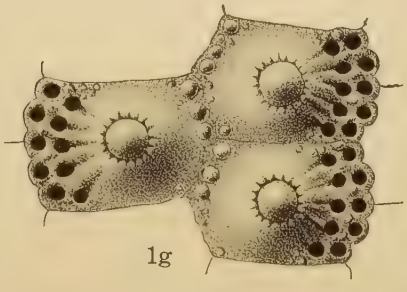
1e



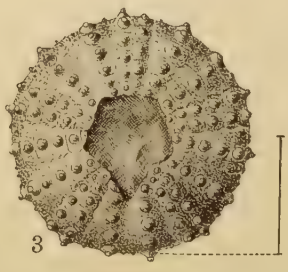
1f

2a

2b



1g



3

CRETACEOUS ECHINOIDEA.

PLATE XXI.

CYPHOSOMA TEXANUM Roemer (p. 60).

U. S. Nat. Mus. 9838.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Tubercle, × 10.
1e. Ambulacrum, × 3.
1f. Portion of interambulacrum, × 3.
1g. Portion of ambulacrum, × 8.

CYPHOSOMA VOLANUM Cragin (p. 61).

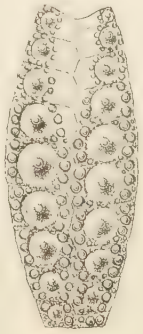
Geol. Survey Texas, type, specimen A.

FIGURE 2a. Upper surface of the test, × 2.
2b. Lower surface of the test, × 2.

CYPHOSOMA VOLANUM Cragin (p. 61).

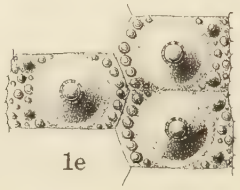
Geol. Survey Texas, type, specimen B.

FIGURE 3. Upper surface of the test.



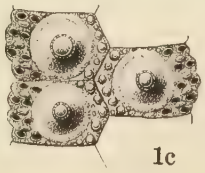
1d

1a

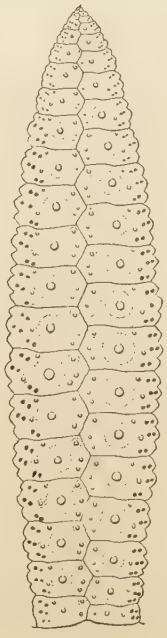


1e

1b

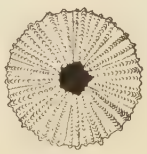


1c

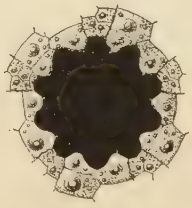


2f

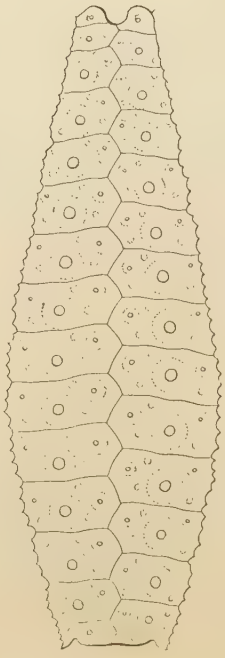
2b



2a

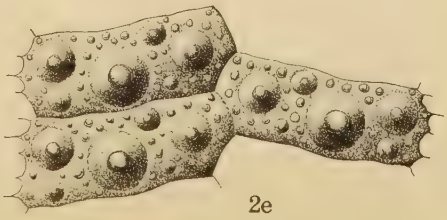


2h



2d

2i



2e

2g

2c

CRETACEOUS ECHINOIDEA.

PLATE XXII.

Coptosoma mortoni (De Loriol) (p. 62).

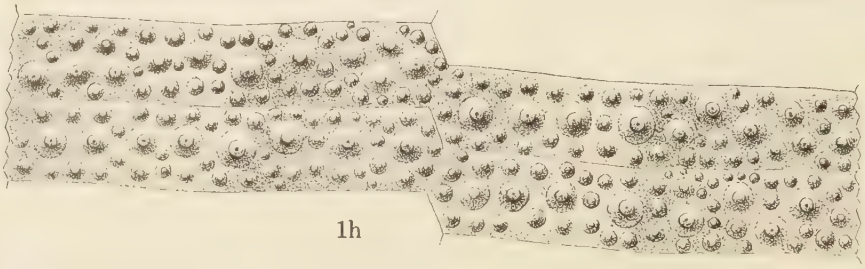
Collection P. de Loriol, type.

Figure 1a. Upper surface of the test.
1b. Lateral surface of the test.
1c. Three ambulacral plates, × 8.
1d. Interambulacrum, × 3.
1e. Three interambulacral plates, × 6.

Psammechinus cingulatus Clark (p. 63).

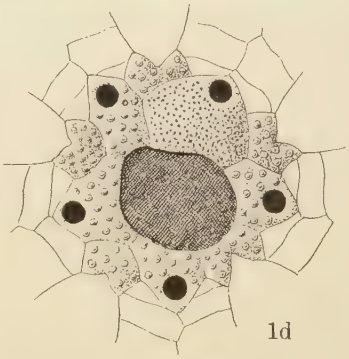
Acad. Nat. Sci. Philadelphia 1467, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral view of the test.
2d. Interambulacrum, × 5.
2e. Three plates of the same × 8.
2f. Ambulacrum, × 5.
2g. Four plates of the same, × 8.
2h. Peristome, × 2.
2i. Tubercle, × 20.

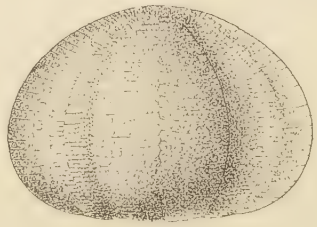


1h

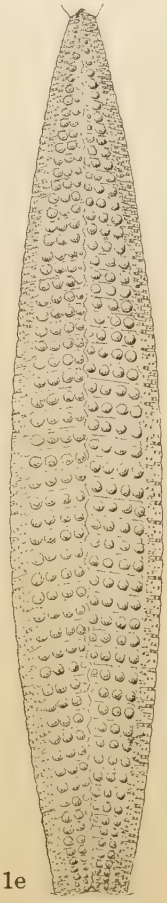
1f



1d



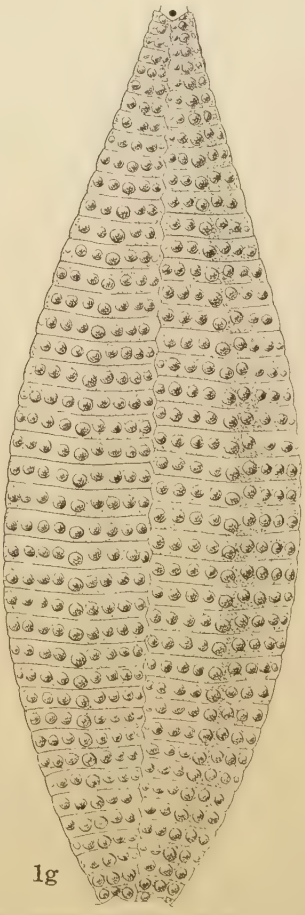
1c



1e

1b

1a



1g

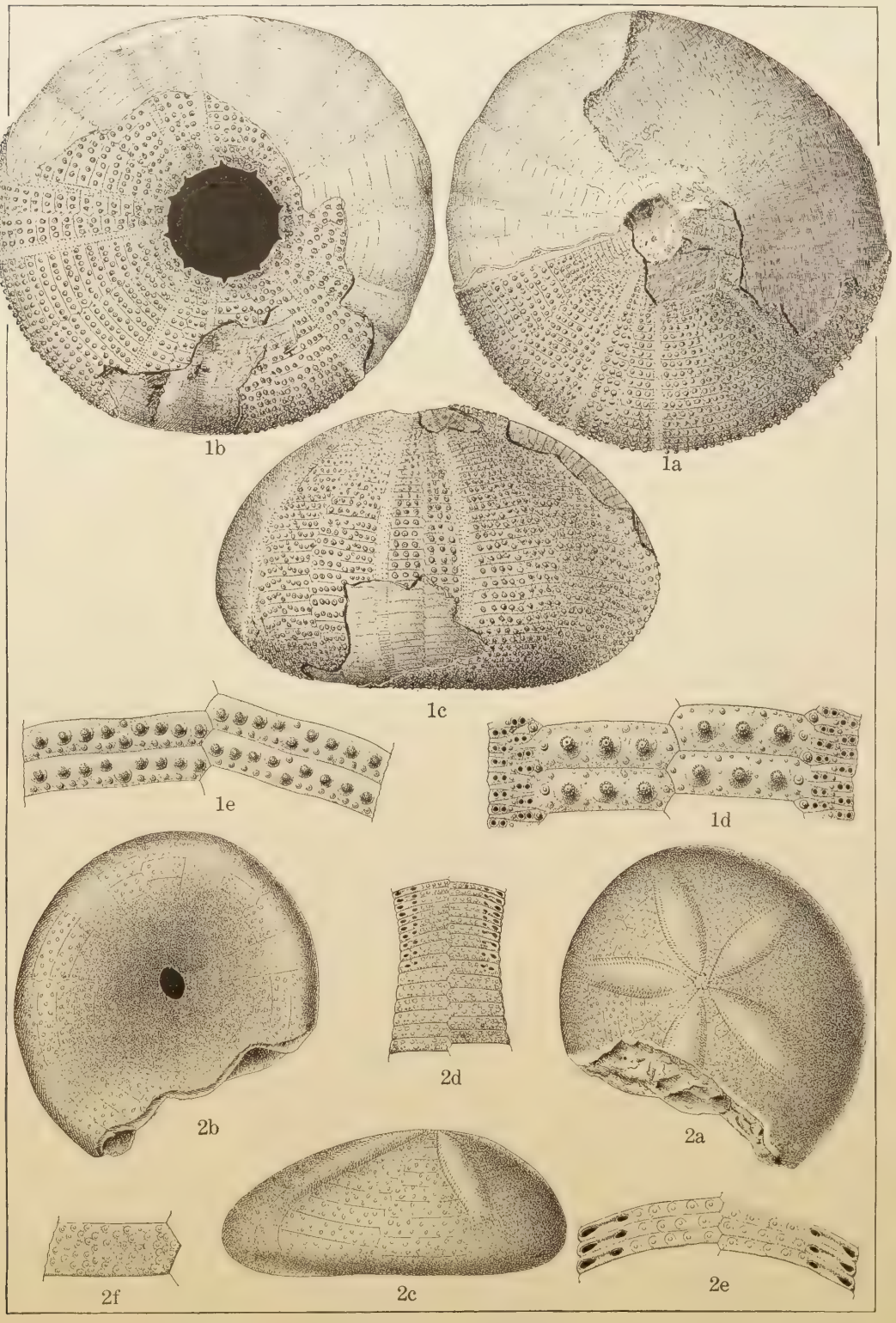
CRETACEOUS ECHINOIDEA.

PLATE XXIII.

PEDINOPSIS SYMMETRICA (Cragin) (p. 64).

Geol. Survey Texas, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Apical system, × 5.
1e. Ambulacrum, × 3.
1f. Portion of ambulacrum, × 8.
1g. Interambulacrum, × 3.
1h. Portion of interambulacrum, × 8.



CRETACEOUS ECHINOIDEA.

PLATE XXIV.

Pedinopsis pondi Clark (p. 65).

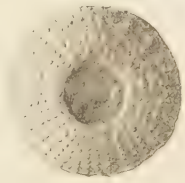
Johns Hopkins Univ. T 3008, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral view of the test.
1d. Four ambulacral plates, × 4.
1e. Four interambulacral plates, × 2.

Botriopygus alabamensis Clark (p. 68).

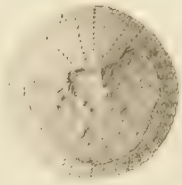
Acad. Nat. Sci. Philadelphia, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Portion of an ambulacrum at base of petaloidal region, × 3.
2e. Same in center of petaloidal region, × 6.
2f. An interambulacral plate, × 3.



1b

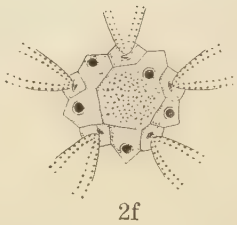
1c



1a

2d

2b



2f

2a

2e

2c

3c

3b

4

3a

CRETACEOUS ECHINOIDEA.

PLATE XXV.

Micropsis lineatus Clark, n. sp. (p. 63).

U. S. Nat. Mus. 31198, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.

Holectypus planatus Roemer (p. 65).

U. S. Nat. Mus. 12236, figured specimen A.

Figure 2a. Upper surface of the test restored.
2b. Lower surface of the test restored.
2c. Lateral surface of the test restored.
2d. Two interambulacral plates, × 3.
2e. Portion of the ambulacrum, × 5.
2f. Apical system, × 5.

Holectypus planatus Roemer (p. 65).

U. S. Nat. Mus. 12236, figured specimen B.

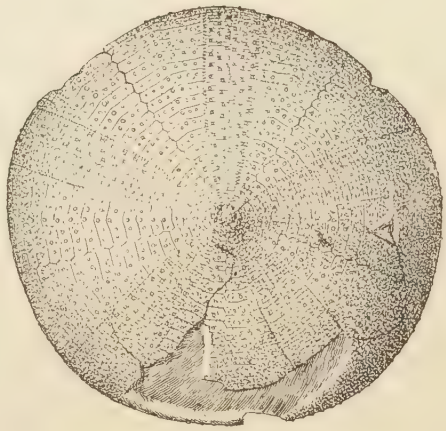
Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.

Holectypus planatus Roemer (p. 65).

Johns Hopkins Univ. T 3008, figured specimen D.

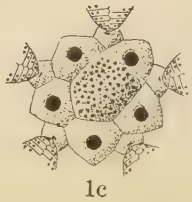
Figure 4. Lateral surface of the test.

1d



1a

1b



1c

1e

CRETACEOUS ECHINOIDEA.

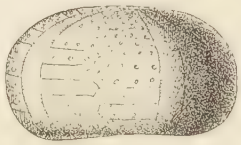
PLATE XXVI.

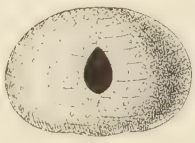
Holectypus planatus Roemer (p. 65).

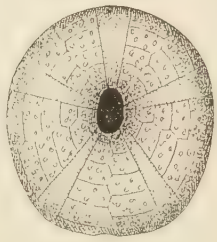
Geol. Survey Texas, figured specimen C.

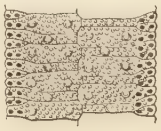
Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Apical system, × 5.
1d. Portion of ambulacrum, × 3.
1e. Portion of interambulacrum, × 3.

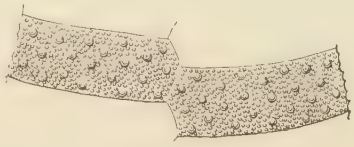
1a

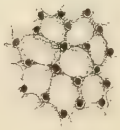

1c

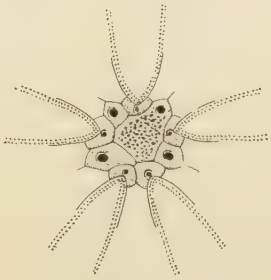

1d

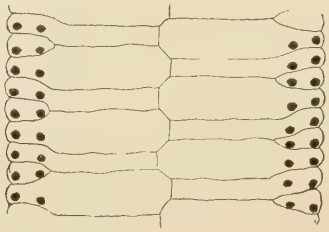

1b


1e


1g


1j

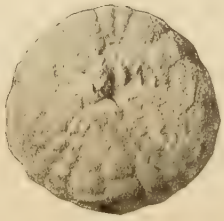

1i


1f

1h

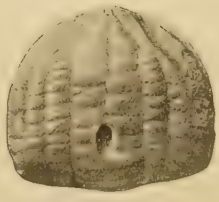
2c

3a


3b

2a

3c


3d

2b

CRETACEOUS ECHINOIDEA.

PLATE XXVII.

Pyrina parryi Hall (p. 67).

U. S. Nat. Mus. 9854.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Portion of ambulacrum, × 5.
1f. Portion of ambulacrum, × 1.
1g. Two interambulacral plates, × 3.
1h. Portion of interambulacral plate.
1i. Apical system.
1j. Portion of madreporite.

Echinobrissus angustatus Clark, n. sp. (p. 69).

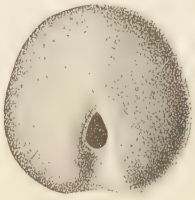
Johns Hopkins Univ. T 3009, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.

Cassidulus conoideus Clark, n. sp. (p. 80).

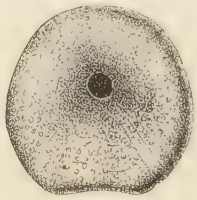
U. S. Nat. Mus. 31199, type.

Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.

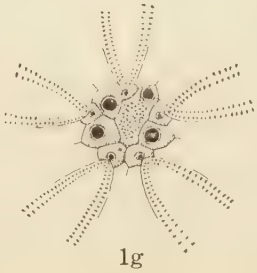


1a

1d

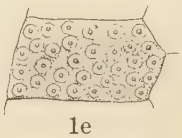


1b



1g

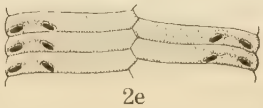
1c



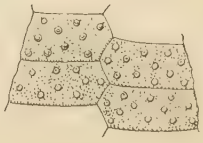
1e

1f

2a



2e

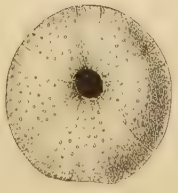


2f

2b

2d

2c



3b

3c

3a

CRETACEOUS ECHINOIDEA.

PLATE XXVIII.

Echinobrissus expansus Clark (p. 69).

Acad. Nat. Sci. Philadelphia 1465, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. An interambulacral plate, × 3.
1f. Portion of the petaloidal region of the right anterolateral ambulacrum, × 8.
1g. Apical system, × 5.

Echinobrissus texanus Clark (p. 70).

U. S. Nat. Mus. 20266, type.

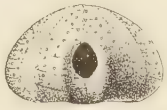
Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.
2e. Portion of the right anterolateral ambulacrum, × 10.
2f. Four interambulacral plates, × 5.

Trematopygus cruciferus (Morton) (p. 71).

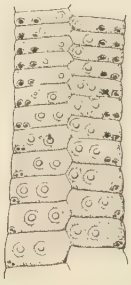
Acad. Nat. Sci. Philadelphia 1464, type.

Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.

1e

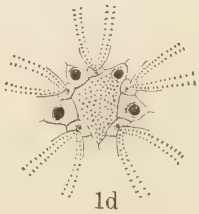


1a



1b

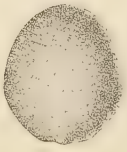
1c



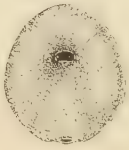
1d

1f

2c



2a

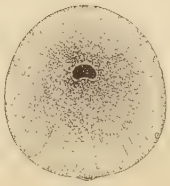


2b

2d

2e

2f

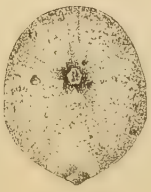


3b

3d

3c

3a



4b

4a

4c

4d

PLATE XXIX.

Trematopygus crucifer (Morton) (p. 71).

Acad. Nat. Sci. Philadelphia 1464, type.

Figure 1a. Posterior surface of the test.
1b. Lower portion of the petaloidal region of the right posterolateral ambulacrum, ×5.
1c. Several plates of the same, × 10.
1d. Apical system, × 5.
1e. Tubercle from above, × 20.
1f. Lateral view of the same, × 20.

Catopygus oviformis Conrad (p. 72).

Acad. Nat. Sci. Philadelphia 1477, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.
2e. Portion of right posterolateral ambulacrum, × 3.
2f. Several plates of the same, × 10.

Catopygus pusillus Clark (p. 73).

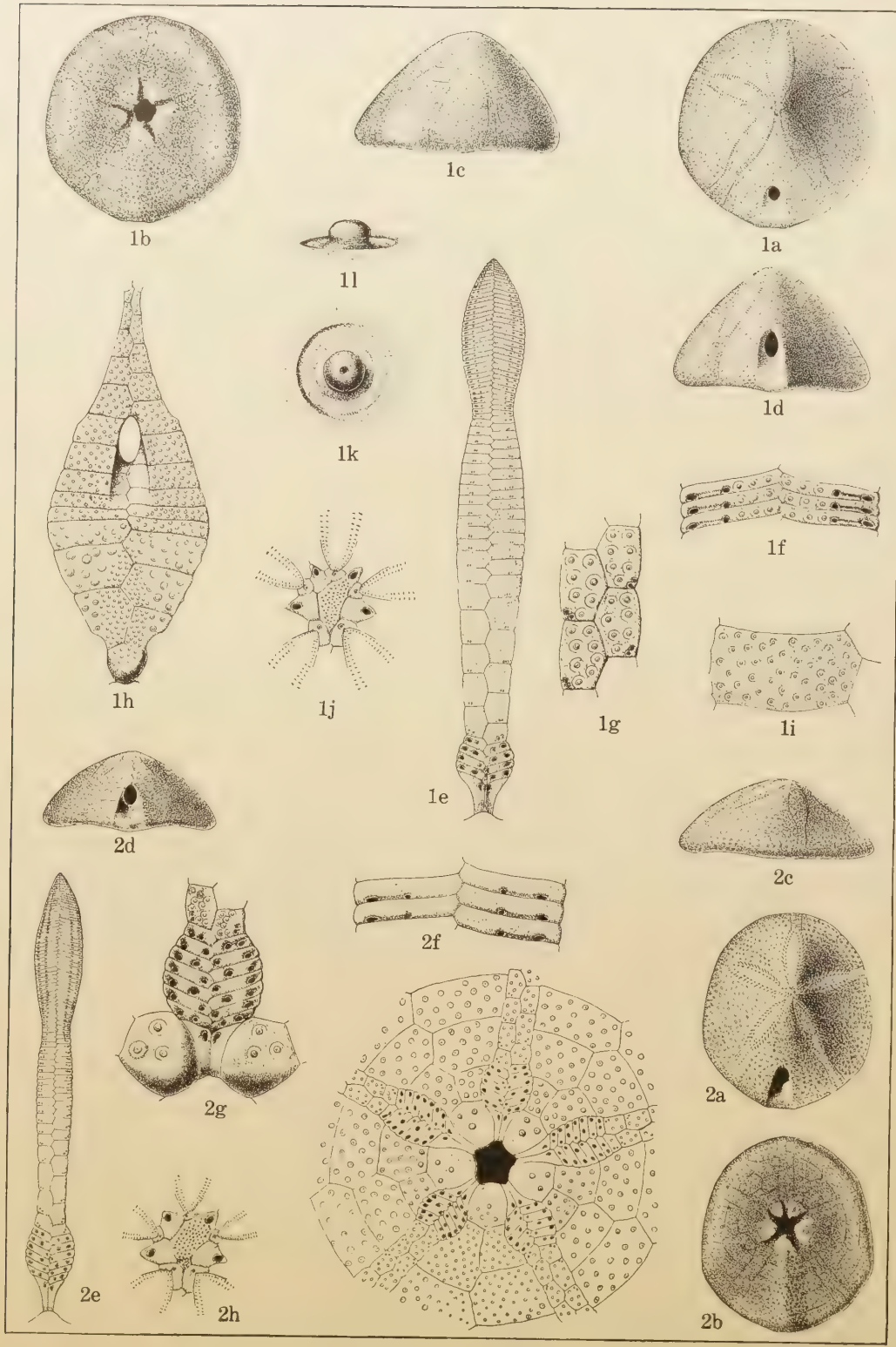
U. S. Nat. Mus. 2210, type.

Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.

Catopygus williamsi Clark (p. 73).

Johns Hopkins Univ. T 3010, type.

Figure 4a. Upper surface of the test.
4b. Lower surface of the test.
4c. Lateral surface of the test.
4d. Posterior surface of the test.



CRETACEOUS ECHINOIDEA.

PLATE XXX.

Cassidulus florealis (Morton) (p. 74).

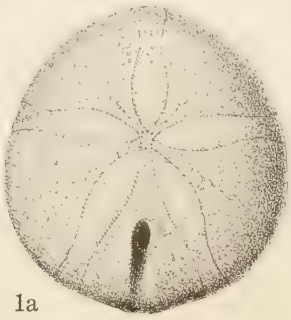
Acad. Nat. Sci. Philadelphia 1495, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Right posterolateral ambulacrum, × 3.
1f. Several plates in the petaloidal region of the same, × 8.
1g. Same, lower surface, × 8.
1h. Posterior interambulacrum, × 2.
1i. Single plate, × 4.
1j. Apical system, × 5.
1k. Tubercle from above, × 20.
1l. Lateral view of the same, × 20.

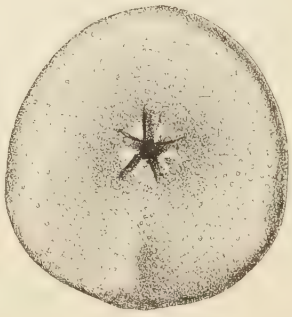
Cassidulus æquoreus Morton (p. 75).

Acad. Nat. Sci. Philadelphia 1475, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.
2e. Anterior ambulacrum, × 2.
2f. Several plates, petaloidal region of the same, × 8.
2g. Same, oral region, × 8.
2h. Apical system, × 5.
2i. Diagram showing the arrangement of the plates about the peristomial opening, × 2


1a

1d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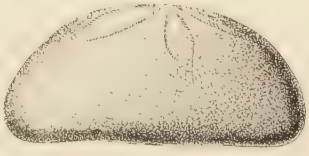
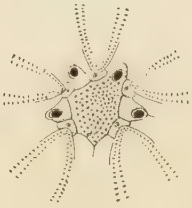

1c

1f


1h

1e

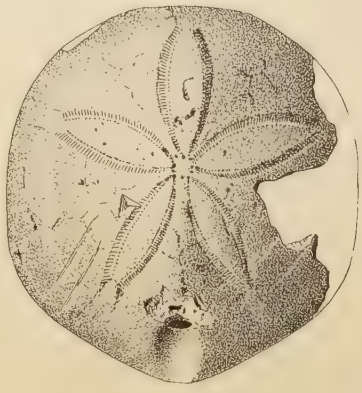
2e

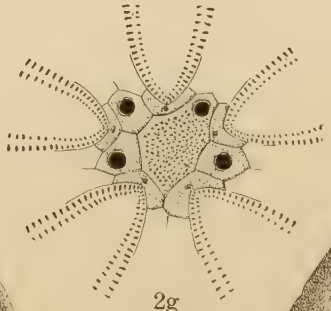
1i

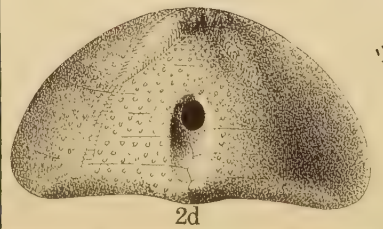
1g

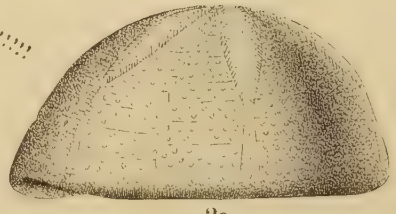
2b

2f


2a


2g


2d


2c

CRETACEOUS ECHINOIDEA.

PLATE XXXI.

Cassidulus micrococcus Gabb (p. 76).

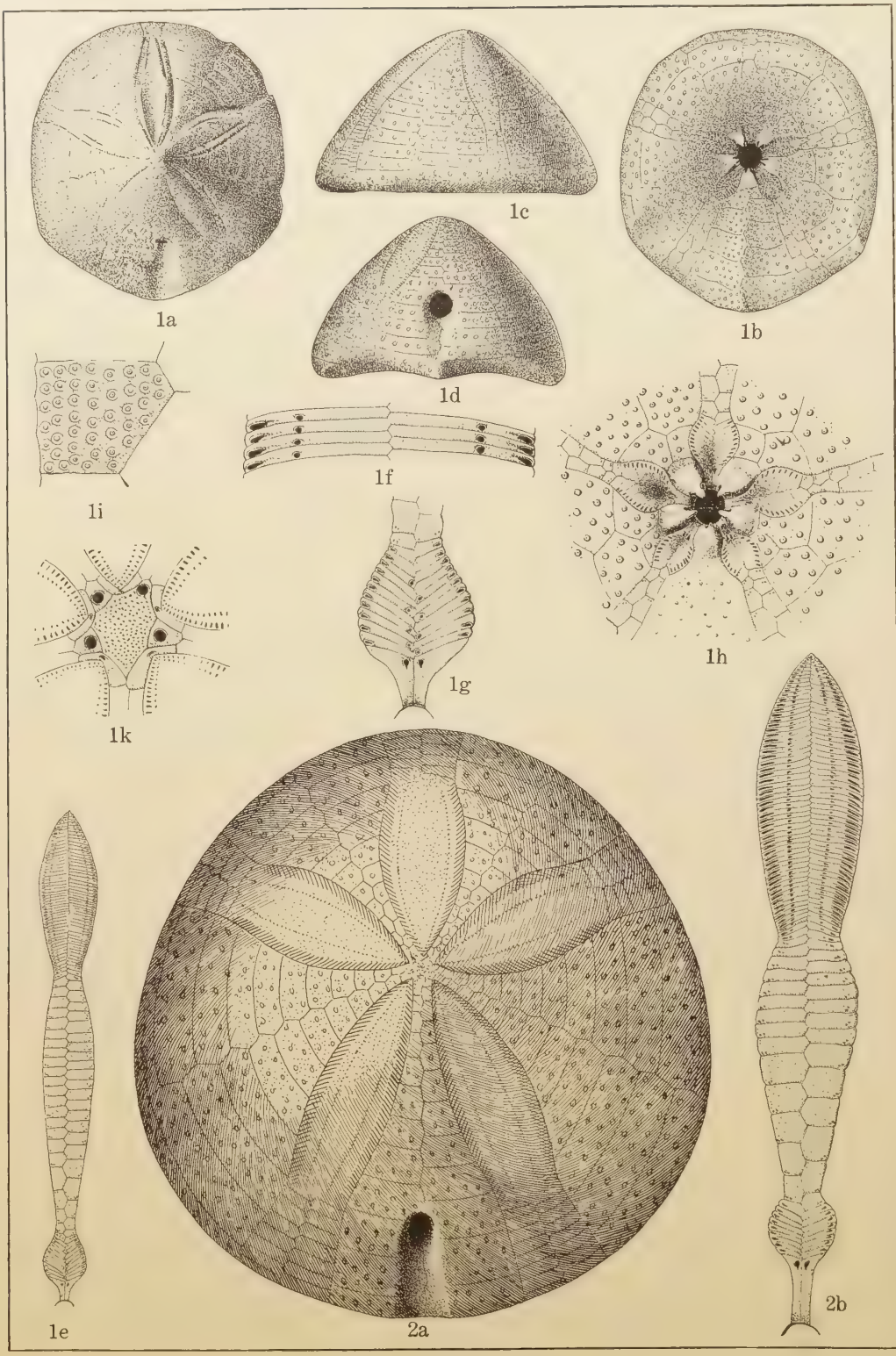
Acad. Nat. Sci. Philadelphia 1480, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Anterior ambulacrum at the base of the petaloidal region, × 2.
1f. Several plates in petaloidal region of the anterior ambulacrum, × 8.
1g. Oral portion of an ambulacrum, × 8.
1h. Apical system, × 5.
1i. Surface of an interambulacral plate, × 20.

Cassidulus subquadratus Conrad (p. 77).

U. S. Nat. Mus. 31200.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.
2e. Lower portion of the petaloidal region of the right anterolateral ambulacrum, × 2.
2f. Oral portion of an ambulacrum, × 5.
2g. Apical system, × 8.



CRETACEOUS ECHINOIDEA.

PLATE XXXII.

Cassidulus subconicus Clark (p. 77).

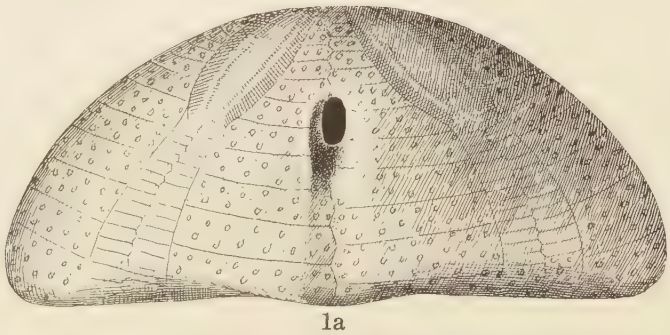
U. S. Nat. Mus. 20264, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Anterior ambulacrum, × 2.
1f. Several plates of the petaloidal portion, × 8.
1g. Same, phylloidal portion, × 6.
1h. Diagram showing the arrangement of the plates around the peristomial opening, × 2.
1i. Interambulacral plate, × 5.
1k. Apical system, × 5.

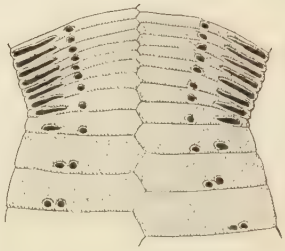
Cassidulus porrectus Clark (p. 78).

U. S. Nat. Mus. 21890, type.

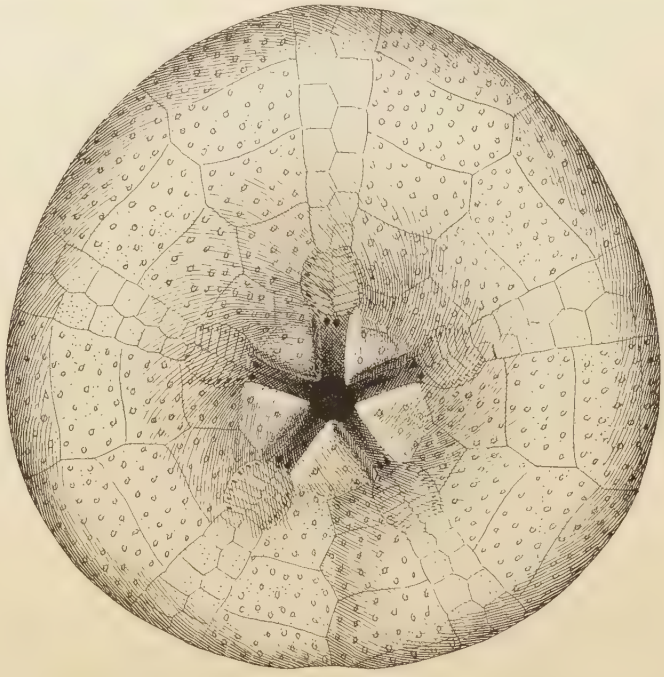
Figure 2a. Upper surface of the test
2b. Anterior ambulacrum, × 1½.



1a



1d

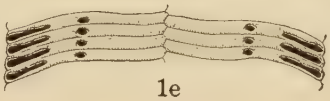


1b

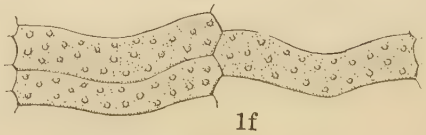
2b

2c

2d

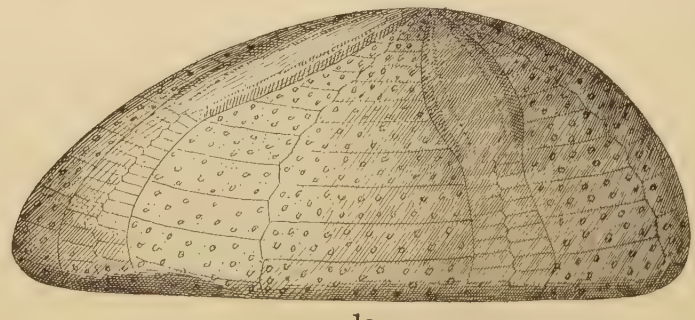


1e



1f

2a



1c

CRETACEOUS ECHINOIDEA.

PLATE XXXIII.

CASSIDULUS PORRECTUS Clark (p. 78).

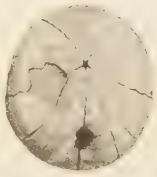
U. S. Nat. Mus. 21890, type.

FIGURE 1a. Posterior surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Lower portion of petaloidal region, × 5.
1e. Central portion of the same, × 5.
1f. Three interambulacral plates, × 2.

CASSIDULUS STANTONI Clark (p. 79).

U. S. Nat. Mus. 20260, type.

FIGURE 2a. Upper surface of the test, × 2.
2b. Lower surface of the test, × 2.
2c. Lateral surface of the test, × 2.
2d. Posterior surface of the test, × 2.



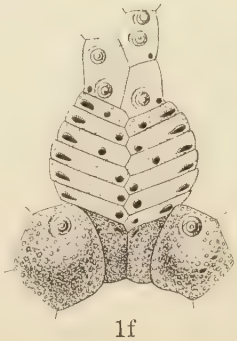
1a

1b

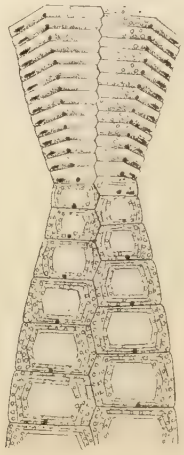
1c

1d

1e



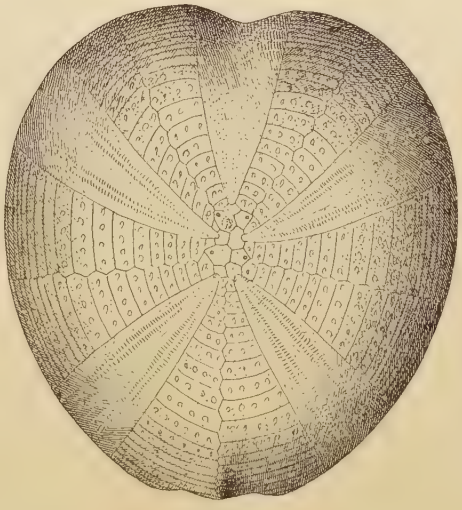
1f



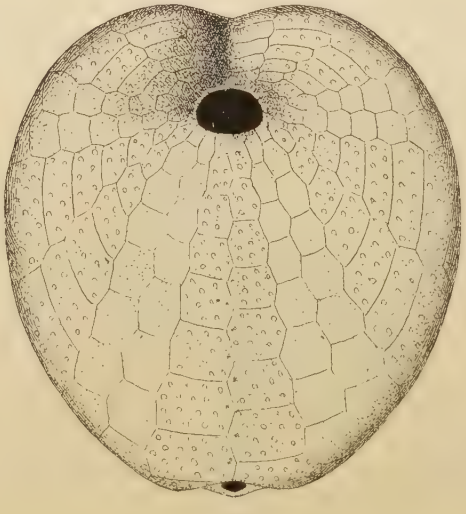
2c

2a

2b



3a



3b

CRETACEOUS ECHINOIDEA.

PLATE XXXIV.

Cassidulus intermedius Slocum (p. 79).

Field Mus. P 10346, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Posterior surface of the test.
1d. Lateral surface of the test.
1e. Portion of left anterior ambulacrum at base of petaloidal region, × 5.
1f. Same, phylloidal portion, × 5.

Cassidulus hemisphericus Slocum (p. 80).

Field Mus. P. 10347, type.

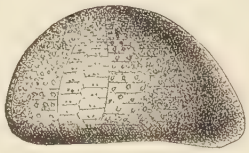
Figure 2a. Upper surface of the test.
2b. Lateral surface of the test.
2c. Portion of anterior ambulacrum at base of petaloidal region, × 5.

Holaster simplex Shumard (p. 85).

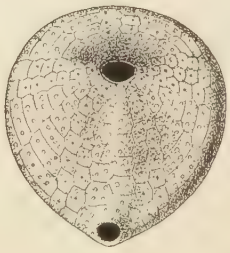
U. S. Nat. Mus. 8382, figured specimen A.

Figure 3a. Upper surface of the test.
3b. Lower surface of the test.

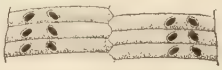
1a



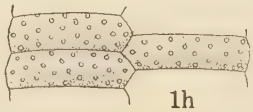
1c



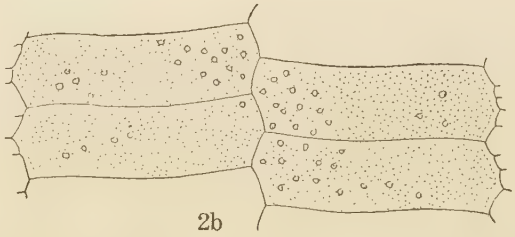
1b



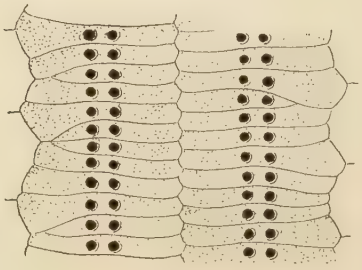
1g



1h



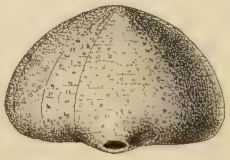
2b



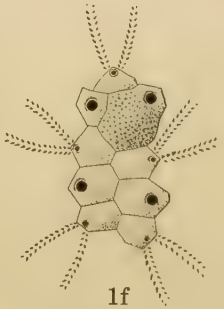
2c

2a

1d



1e



1f

CRETACEOUS ECHINOIDEA.

PLATE XXXV.

Ananchytes ovalis Clark (p. 81).

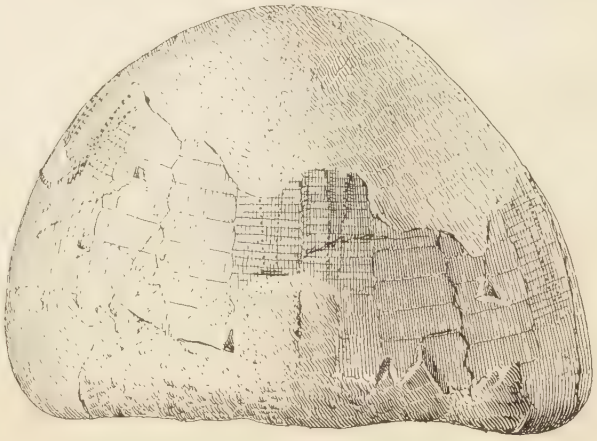
Johns Hopkins Univ. T 3011, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Anterior surface of the test.
1e. Posterior surface of the test
1f. Apical system, × 5.
1g. Ambulacral plates, × 5.
1h. Interambulacral plates, × 3.

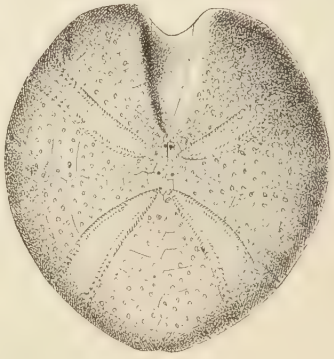
Ananchytes texana Cragin (p. 82).

Geol. Survey Texas, type.

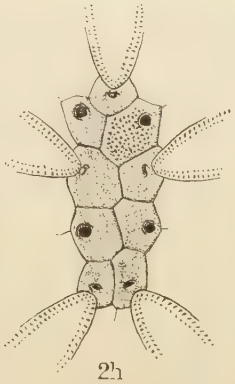
Figure 2a. Lower surface of the test.
2b. Portion of ambulacrum, × 2.
2c. Portion of interambulacrum, × 2.



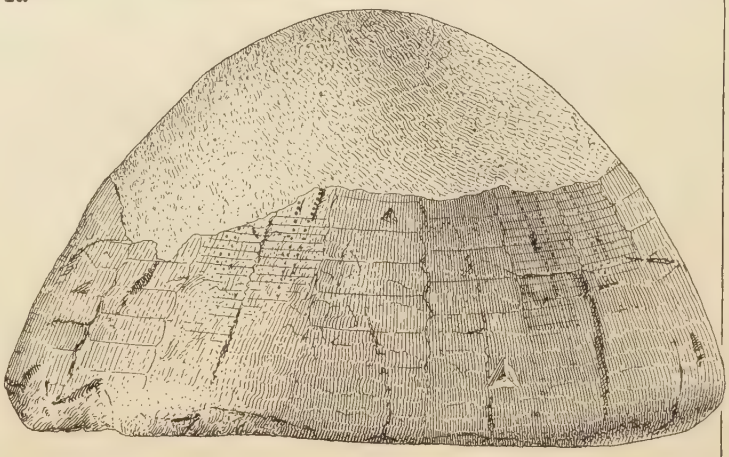
1a



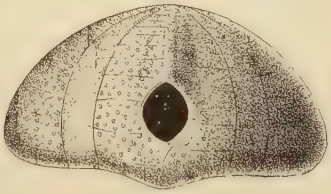
2a



2h



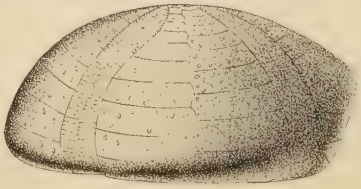
1b



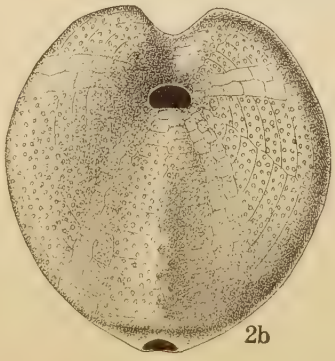
2e

3a

3b

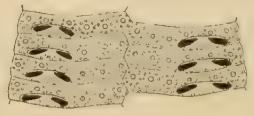


2c



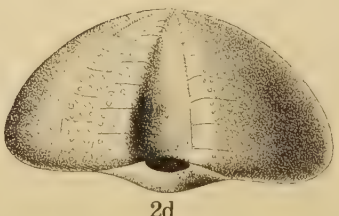
2b

3c



2f

2g



2d

CRETACEOUS ECHINOIDEA.

PLATE XXXVI.

Ananchytes texana Cragin (p. 82).

Geol. Survey Texas, type.

Figure 1a. Anterior surface of the test.
1b. Lateral surface of the test.

Cardiaster cinctus (Morton) (p. 83).

Acad. Nat. Sci. Philadelphia 1485, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Anterior surface of the test.
2e. Posterior surface of the test.
2f. Central portion of the petaloidal region of an ambulacral area, × 5.
2g. Basal portion of same, × 4.
2h. Apical system, × 5.

Cardiaster smocki Clark (p. 84).

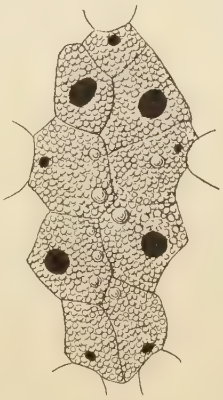
Geol. Survey New Jersey, type.

Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.

1a

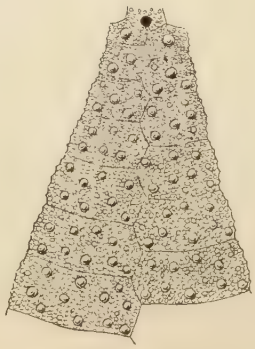
1c

1b

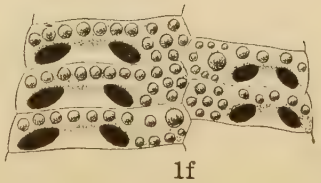


1d

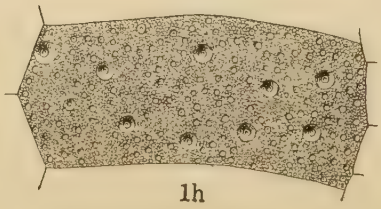
1e



1g



1f



1h

CRETACEOUS ECHINOIDEA.

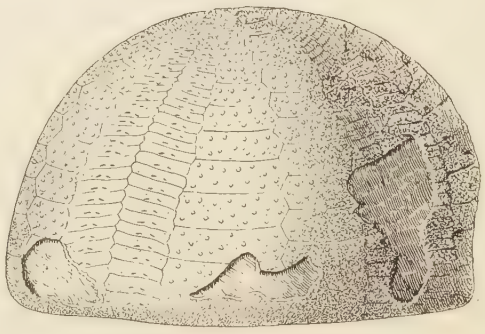
PLATE XXXVII.

CARDIASTER CURTUS Clark, n. sp. (p. 84).

U. S. Nat. Mus. 31201, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test
1d. Apical system, × 10.
1e. Portion of ambulacrum, × 10.
1f. Several plates of same, × 15.
1g. Portion of interambulacrum, × 10.
1h. Interambulacral plate, × 15.

1g

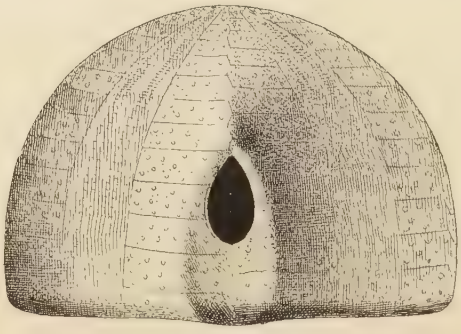


1a

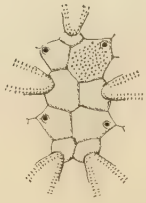
1f

1d

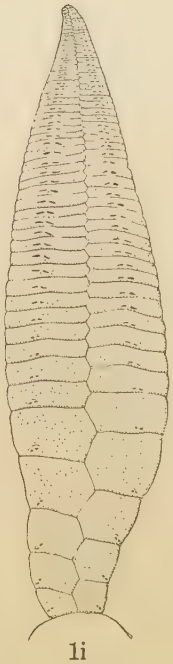
1h



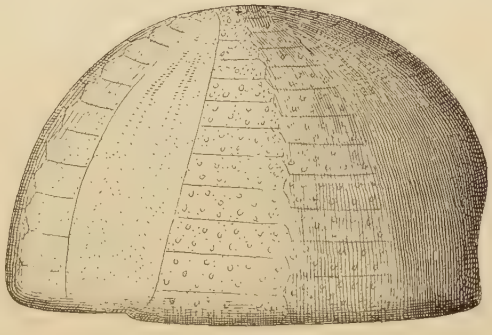
1c



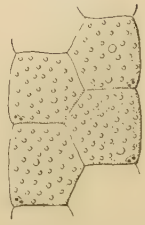
1j



1i



1b



1e

CRETACEOUS ECHINOIDEA.

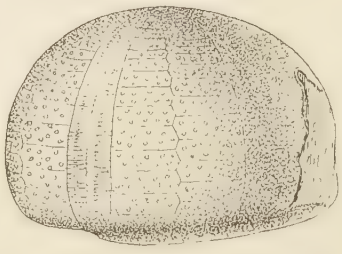
PLATE XXXVIII.

HOLASTER SIMPLEX Shumard (p. 85).

U. S. Nat. Mus. 8382, figured specimen A.

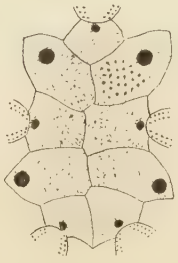
FIGURE 1a. Lateral surface of the test.
1b. Lateral surface of the test restored.
1c. Posterior surface of the test.
1d. Portion of the ambulacrum, × 3.
1e. Portion of the ambulacrum, × 3.
1f. Tubercle, × 10.
1g. Tubercle, × 10.
1h. Interambulacral plate, × 3.
1i. Right anterolateral ambulacrum, × 2.
1j. Apical system, × 3.

1b

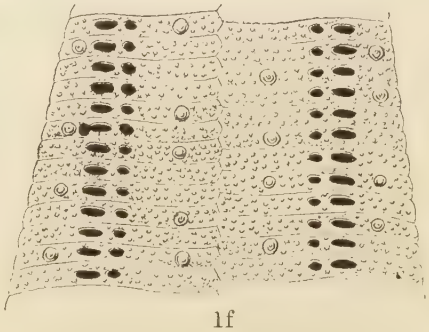


1c

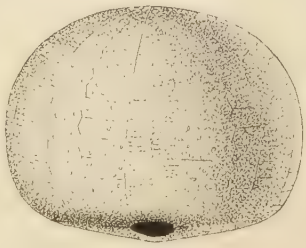
1a



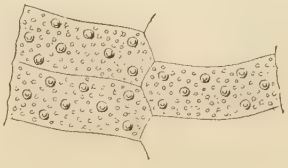
1e



1f

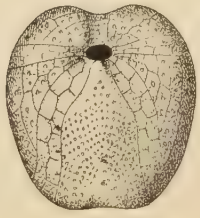


1d

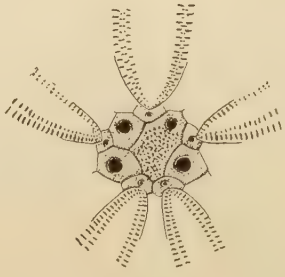


1g

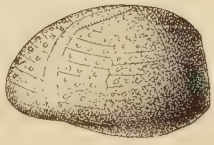
2e



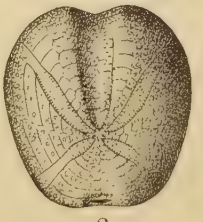
2b



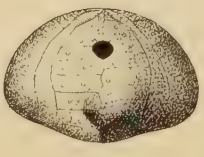
2g



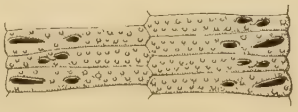
2c



2a



2d



2f

CRETACEOUS ECHINOIDEA.

PLATE XXXIX.

Holaster simplex Shumard (p. 85).

Geol. Survey Texas, figured specimen B.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Anterior surface of the test.
1e. Apical system, × 4.
1f. Portion of ambulacrum, × 10.
1g. Three interambulacral plates, × 5.

Enallaster texanus (Roemer) (p. 86).

U. S. Nat. Mus. 9857.

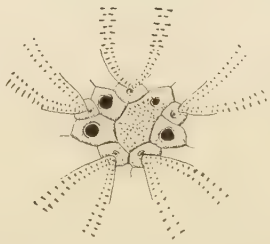
Figure 2a. Upper view of the test.
2b. Lower view of the test.
2c. Posterior view of the test.
2d. Posterior view of the test.
2e. Portion of the petaloidal region of the right anterolateral ambulacrum, × 10.
2f. Portion of the anterior ambulacrum, × 10.
2g. Apical system, × 6.

1b

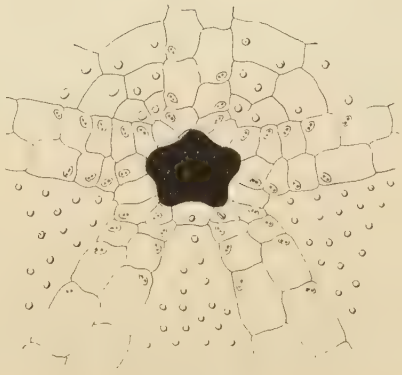
1a

1d

1e



1i



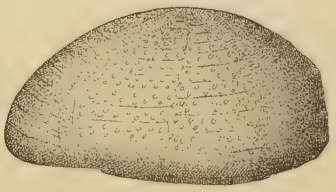
1h

1l

1f

1g

1k



1c

CRETACEOUS ECHINOIDEA.

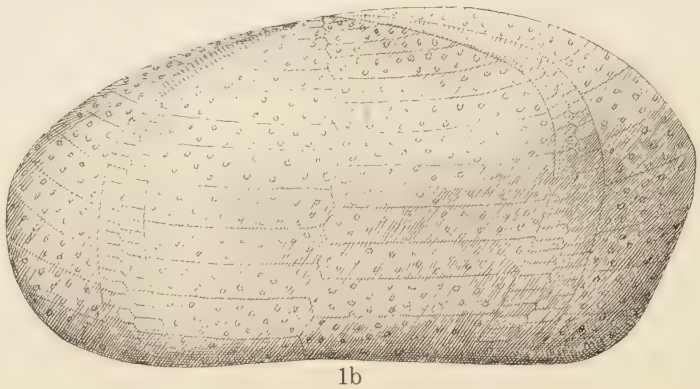
PLATE XL.

Enallaster obliquatus Clark (p. 87).

U. S. Nat. Mus. 12237, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral view of the test.
1d. Posterior view of the test.
1e. Portion of the petaloidal region of the anterior ambulacrum, × 8.
1f. Same, left anterior ambulacrum, × 8.
1g. Second plate of the same from the mouth opening, × 8.
1h. Diagram showing arrangement of plates about the mouth opening, × 3.
1i. Apical system, × 6.
1k. Tubercle from above, × 10.
1l. Lateral view of the same, × 10.

39800°—15——21



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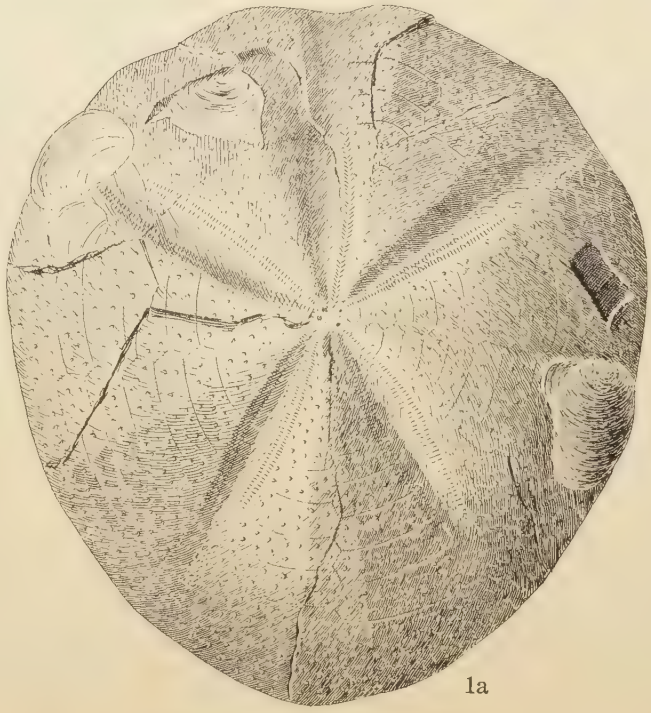

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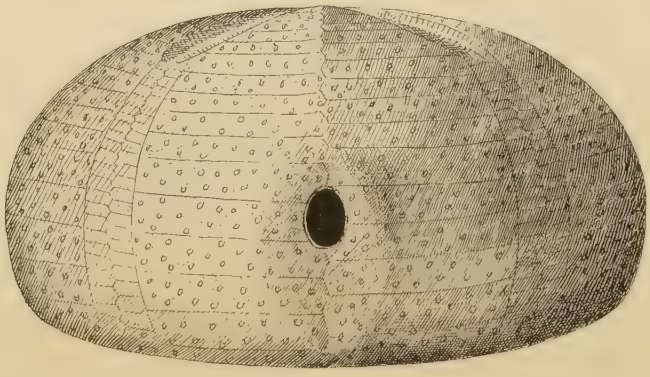


1c

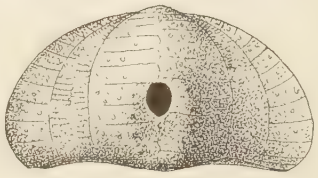
CRETACEOUS ECHINOIDEA.

PLATE XLI.

HEMIASTER ELEGANS Shumard (p. 88).

U. S. Nat. Mus. 21887.

FIGURE 1a. Upper surface of the test.
1b. Lateral surface of the test.
1c. Posterior surface of the test.



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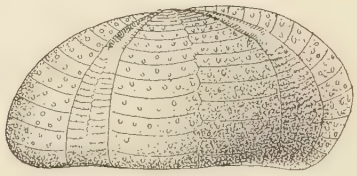
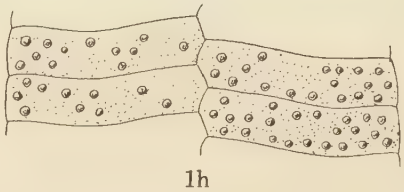
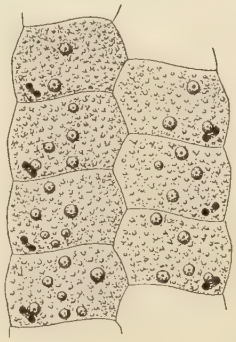


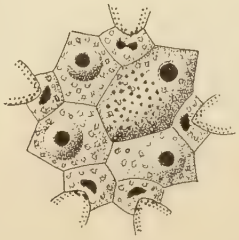
1c



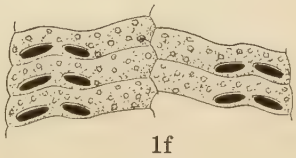
1h



1g

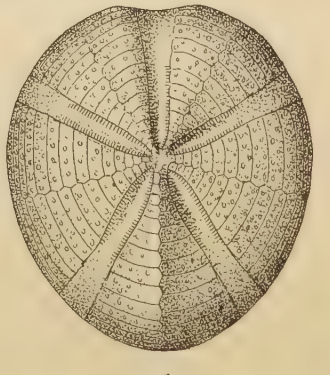


1e



1f

1b



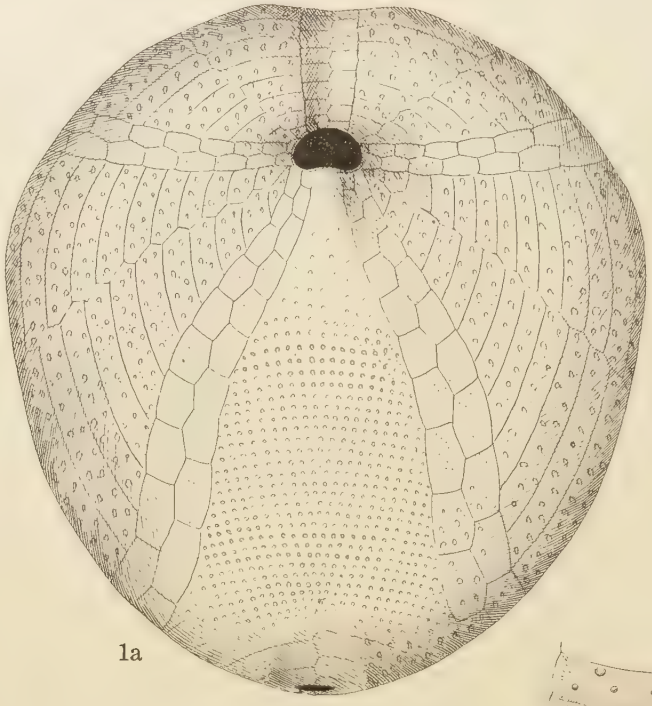
1a

PLATE XLII.

Hemiaster elegans Shumard (p. 88).

Geol. Survey Texas.

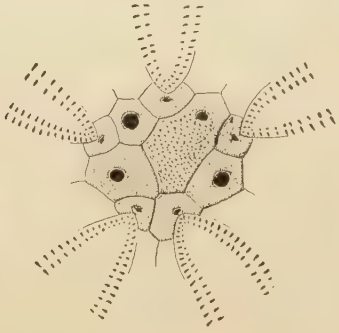
Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Apical system, × 5.
1f. Portion of anterior ambulacrum, × 5.
1g. Same.
1h. Portion of interambulacrum, × 5.



1a

1f

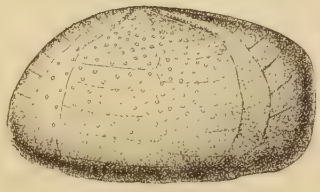
1d



1e

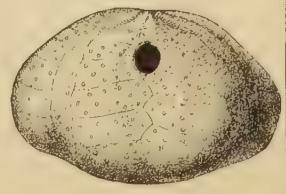
1c

1b



2c

2a



2b

CRETACEOUS ECHINOIDEA.

PLATE XLIII.

HEMIASTER ELEGANS Shumard (p. 88).

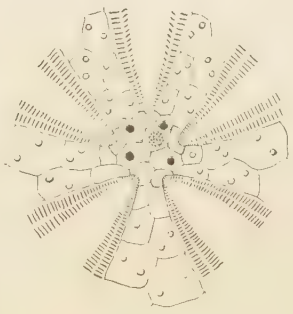
U. S. Nat. Mus. 21887.

FIGURE 1a. Lower portion of the test.
1b. Middle portion of the petaloidal region of the anterior ambulacrum, × 5.
1c. Same, left anterolateral ambulacrum, × 5.
1d. Two interambulacral plates, × 3.
1e. Apical system, × 5.
1f. Upper portion of the anterior ambulacrum, × 3.

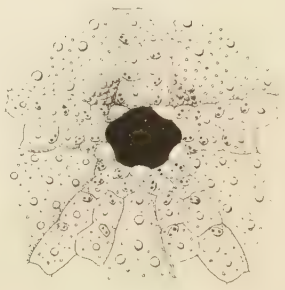
HEMIASTER WHITEI Clark (p. 89).

U. S. Nat. Mus. 9732 type.

FIGURE 2a. Upper surface of the test.
2b. Posterior surface of the test.
2c. Lateral surface of the test.

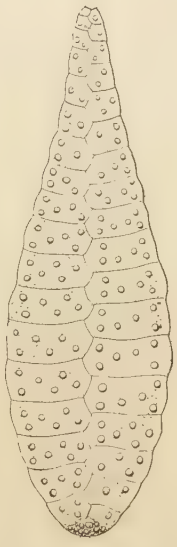


1h



1e

1g



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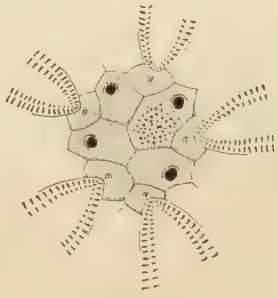

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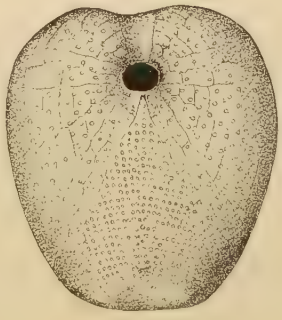


1a

1c

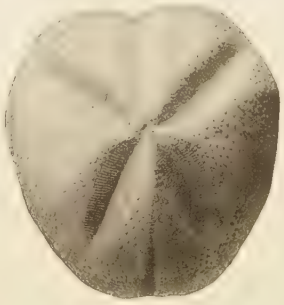
1d

PLATE XLIV.

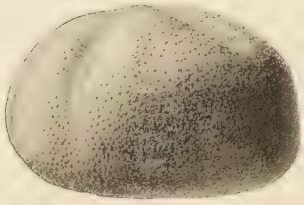
Hemiaster whitei Clark (p. 89).

U. S. Nat. Mus. 9732, type.

Figure 1a. Lower surface of the test.
1b. Right anterolateral interambulacrum, × 3.
1c. Lower portion of the petaloidal region of the right anterolateral ambulacrum, × 8.
1d. Several plates of the petaloidal region of the left anterolateral ambulacrum, × 8.
1e. Peristomial opening, with surrounding ambulacral and interambulacral plates, × 3.
1f. Apical system, × 5.
1g. Left anterolateral ambulacrum, × 3.
1h. Diagram showing the arrangement of the plates in the apical system and bordering areas, × 3.



1a



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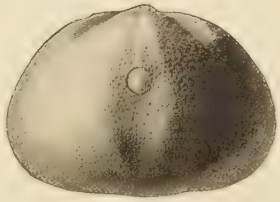
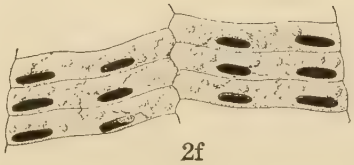


1c

2c



2f

2d

2a

2e

2b

CRETACEOUS ECHINOIDEA.

PLATE XLV.

HEMIASTER WHITEI Clark (p. 89).

U. S. Nat. Mus. 31202.

FIGURE 1a. Upper surface of the test.
1b. Lateral surface of the test.
1c. Posterior surface of the test.

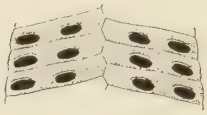
HEMIASTER WHITEI Clark (p. 89).

U. S. Nat. Mus. 4544.

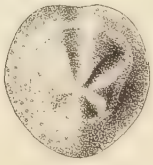
FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.
2e. Apical system, × 5.
2f. Portion of ambulacrum, × 8.

1d

1b

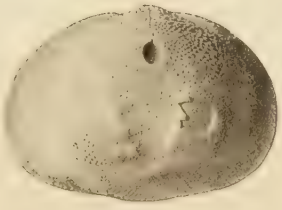


1e

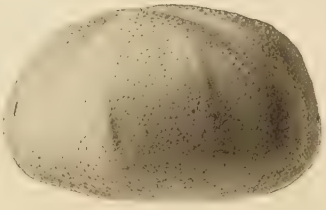


1a

1c

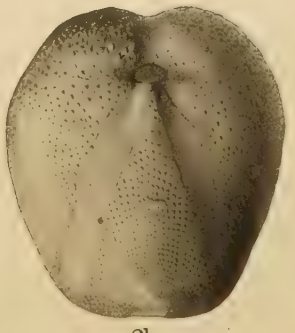


2d



2c

2a



2b

CRETACEOUS ECHINOIDEA.

PLATE XLVI.

Hemiaster bexari Clark, n. sp. (p. 89).

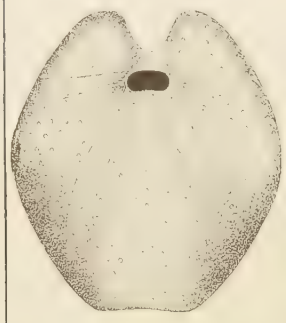
U. S. Nat. Mus. 8330, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Portion of ambulacrum, × 5.

Hemiaster comanchei Clark, n. sp. (p. 90).

Johns Hopkins Univ. T 3012, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.



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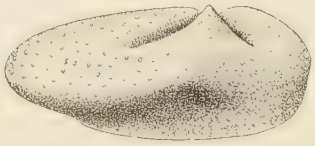
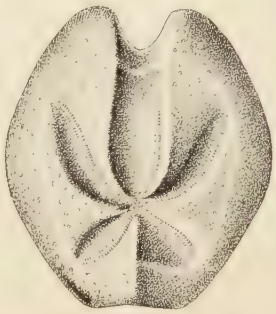


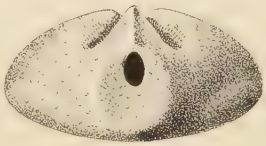
1d



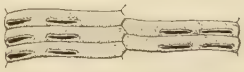
1b

1a

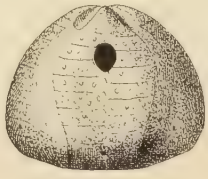
1f



1e

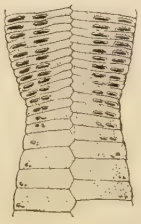


2e

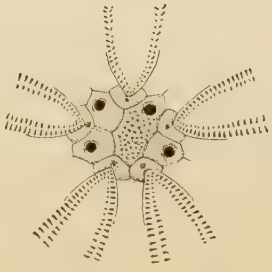


2d

2h



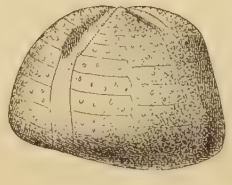
2f



2i

2g

2b



2c

2a

CRETACEOUS ECHINOIDEA.

PLATE XLVII.

Hemiaster dalli Clark (p. 90).

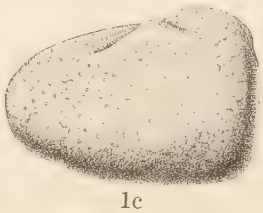
U. S. Nat. Mus. 19114, type.

Figure 1a. Upper surface of the test
1b. Upper surface of the test restored.
1c. Lower surface of the test.
1d. Lateral surface of the test.
1e. Posterior surface of the test.
1f. Several plates from the petaloidal portion of the left anterolateral ambulacrum, × 5.

Hemiaster calvini Clark (p. 90).

U. S. Nat. Mus. 12241, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral view of the test.
2d. Posterior view of the test.
2e. Several plates from the petaloidal region of the right posterolateral ambulacrum, × 5.
2f. Same, lower portion of petaloidal region, × 5.
2g. Several plates from anterior ambulacrum, × 5.
2h. Interambulacral plate, × 3.
2i. Apical system, × 5.


1c

1b

1d

1a

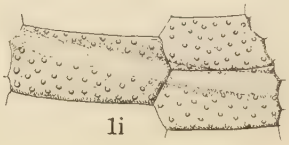
1l

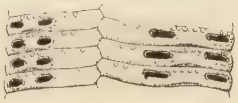
1m

1e

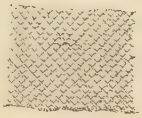
1f

1g


1i


1h

1n


1k

2d

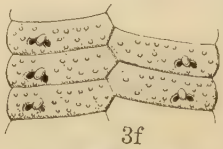
2c

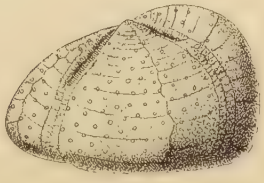
3e

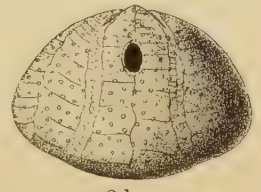
2b

2a

3g


3f


3c


3d

3b

3a

CRETACEOUS ECHINOIDEA.

PLATE XLVIII.

Hemiaster parastatus (Morton) (p. 92).

Acad. Nat. Sci. Philadelphia 1487, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Anterior ambulacrum, × 2.
1f. Portion of petaloidal region of the same, × 8.
1g. Portion of basal region, ditto, × 5.
1h. Several plates from the petaloidal region of the right anterolateral ambulacrum, × 5.
1i. Three interambulacral plates, with fasciole, × 3.
1k. Portion of fasciole, × 10.
1l. Tubercle from the side, × 20.
1m. Same from above, × 20.
1n. Apical system, × 5.

Hemiaster stella (Morton) (p. 93).

U. S. Nat. Mus. 2208.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.

Hemiaster ungula (Morton) (p. 93).

Acad. Nat. Sci. Philadelphia 1503, type.

Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.
3e. Portion of the petaloidal region of the right anterolateral ambulacrum, × 8.
3f. Same, anterior ambulacrum, × 8.
3g. Apical system, × 5.

1c

1j

1g

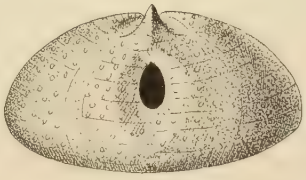
1b

1f

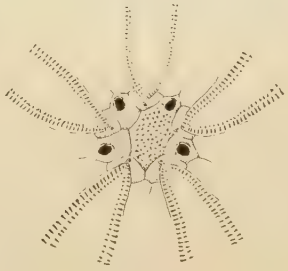
1a

1i

1d

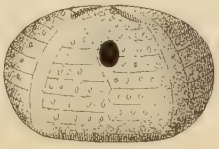


1e



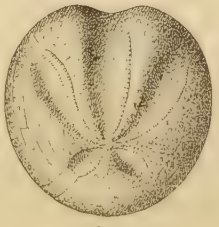
1h

2e



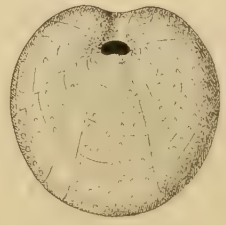
2d

2f



2a

2c



2b

CRETACEOUS ECHINOIDEA.

PLATE XLIX.

Hemiaster texanus Roemer (p. 94).

Johns Hopkins Univ. T 3013.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test restored, × 1½.
1c. Lower surface of the test, ditto, × 1½.
1d. Lateral surface of the test, × 1½.
1e. Posterior surface of the test, ditto, × 1½.
1f. Several plates from the petaloidal region of the right posterolateral ambulacrum, × 8.
1g. Same, anterior ambulacrum, × 8.
1h. Apical system, × 5.
1i. Lateral view of a tubercle, × 20.
1j. Tubercle from above, × 20.

Hemiaster humphreysanus Meek and Hayden (p. 95).

U. S. Nat. Mus. 331, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.
2e. Several plates from the petaloidal portion of the left anterolateral ambulacrum, × 8.
2f. Several plates from the petaloidal portion of the anterior ambulacrum, × 8.

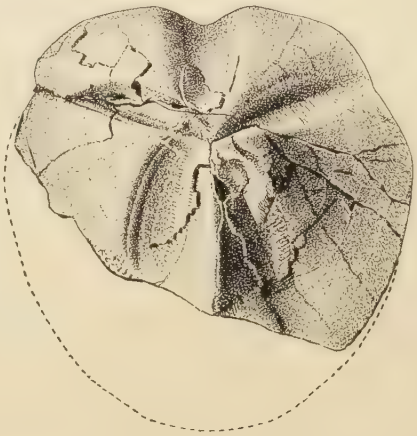
1b

1d

1c

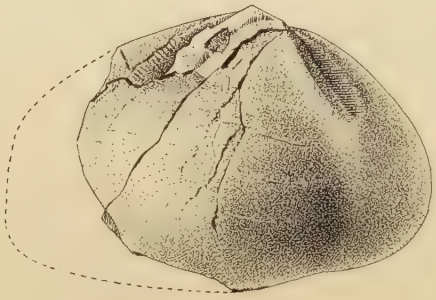
1a

2b

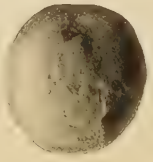


2a

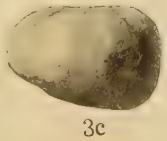
3a



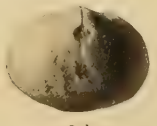
2c



3b



3c



3d

CRETACEOUS ECHINOIDEA.

PLATE L.

Hemiaster californicus Clark (p. 96).

U. S. Nat. Mus. 31203, type.

Figure 1a. Upper surface of the test.
1b. Upper surface of the test, restored.
1c. Lower surface of the test.
1d. Lateral surface of the test.

Hemiaster beecheri Clark, n. sp. (p. 96).

Peabody Museum, Yale University, 1863, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.

Hemiaster lacunosus Slocum (p. 97).

U. S. Nat. Mus. 31204, type.

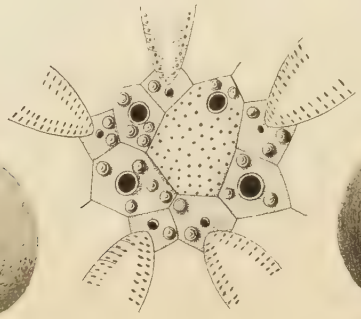
Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.

1a

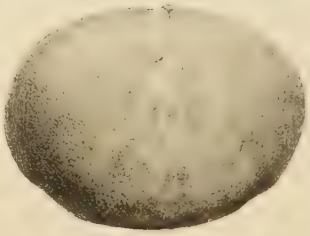
1i

1b

1c



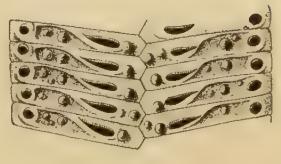
1e



1d

1h

1f



1g

PLATE LI.

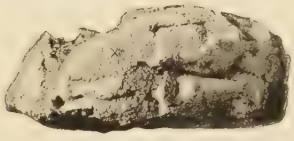
HEMIASTER LACUNOSUS Slocum (p. 97).

Field Mus. P 10342, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Apical system, × 10.
1f. Portion of anterior ambulacrum, × 8.
1g. Same, petaloidal region, × 8.
1h. Lateral view of tubercle, × 20.
1i. Tubercle from above, × 20.

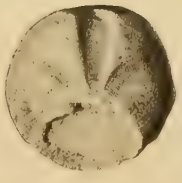
1a

1b



1c

2c



2a

2b

PLATE LII.

Hemiaster kümmeli Clark (p. 97).

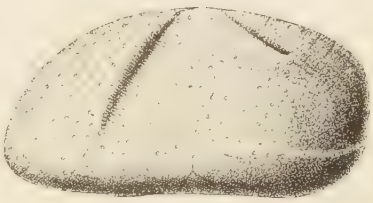
Geol. Survey New Jersey, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.

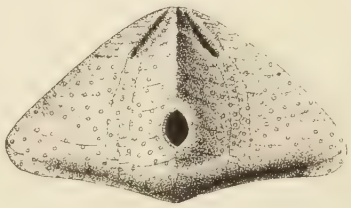
Hemiaster welleri Clark (p. 98).

Geol. Survey New Jersey, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.

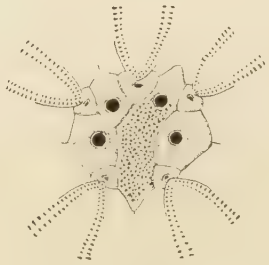


1c



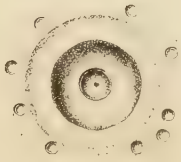
1d

1e



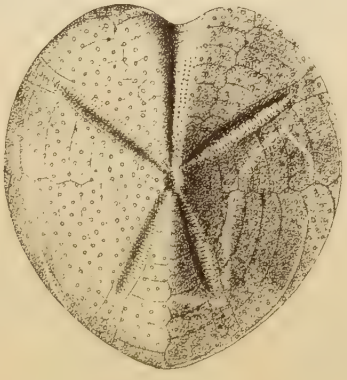
1g

1h



1i

1f



1a

1b

CRETACEOUS ECHINOIDEA.

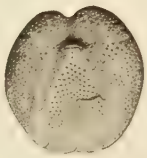
PLATE LIII.

Linthia tumidula Clark (p. 99).

Am. Mus. Nat. Hist., type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Upper portion of the anterior ambulacrum, × 5.
1f. Several plates from the petaloidal region of the left posterolateral ambulacrum, × 8.
1g. Apical system, × 5.
1h. Tubercle from the side, × 20.
1i. Tubercle from above, × 20.

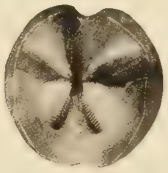
1a



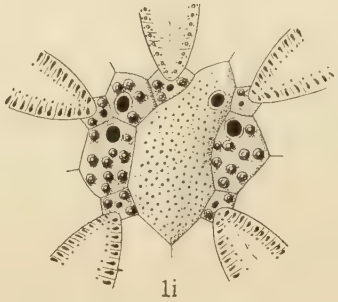
1b

1d

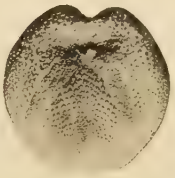
1c



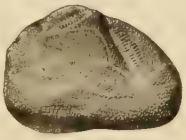
1e



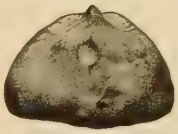
1i



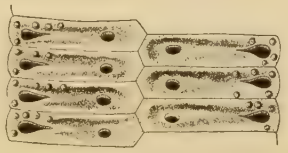
1f



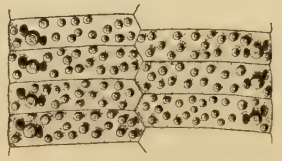
1g



1h



1k



1l

CRETACEOUS ECHINOIDEA.

PLATE LIV.

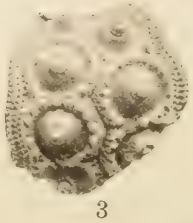
LINTHIA VARIABILIS Slocum (p. 99).

Field Mus. P 10457, type.

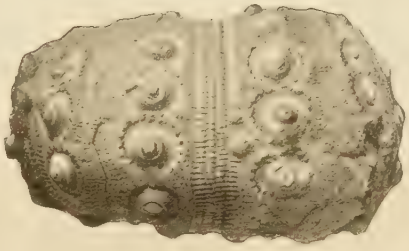
FIGURE 1a. Upper surface of the test (P 10457).
1b. Lower surface of the test (P 10457).
1c. Lateral surface of the test (P 10457).
1d. Posterior surface of the test (P 10457).
1e. Upper surface of the test (P 10457).
1f. Lower surface of the test (P 10457).
1g. Lateral surface of the test (P 10457).
1h. Posterior surface of the test (P 10457).
1i. Apical system, × 10.
1k. Portion of ambulacrum, × 20.
1l. Portion of ambulacrum, × 8.

1a

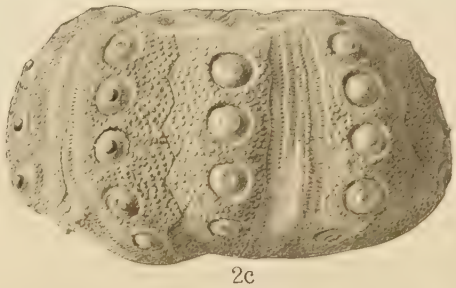
1b



3



1c



2c

2a

4

2b

EOCENE ECHINOIDEA.

PLATE LV.

CIDARIS MITCHELLI Emmons (p. 113).

Williams College, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.

CIDARIS CAROLINENSIS Emmons (p. 113).

Williams College, type.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.

CIDARIS PRATTI Clark, n. sp. (p. 114).

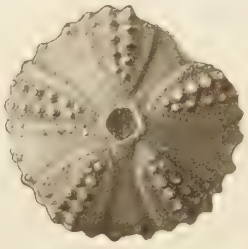
U. S. Nat. Mus. 164663, type.

FIGURE 3. Portion of interambulacrum with adjoining ambulacra.

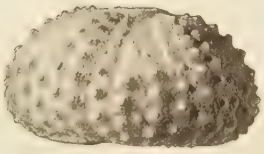
CIDARIS MERRIAMI Arnold (p. 114).

U. S. Nat. Mus. 165438, type.

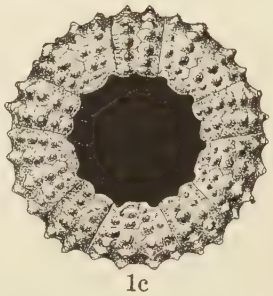
FIGURE 4. Spine, after Arnold.



1a

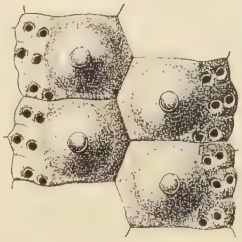


1b

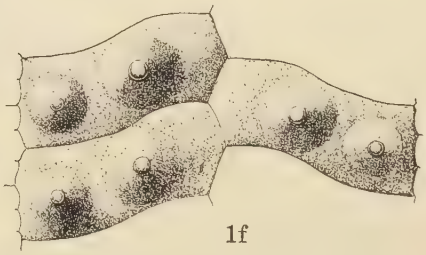


1c

1d

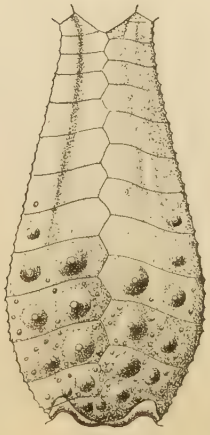


1e

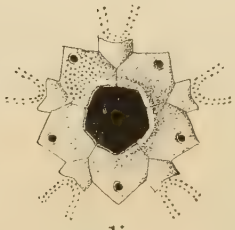


1f

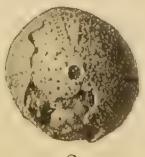
1h



1g



1i



2a

2b

3

EOCENE ECHINOIDEA.

PLATE LVI.

Œlopleurus infulatus (Morton) (p. 117).

Acad. Nat. Sci. Philadelphia 1076.

Figure 1a. Upper surface of the test, × 2.
1b. Lateral surface of the test, × 2.
1c. Lower surface of the test, × 2.
1d. Upper portion of an ambulacrum, × 6.
1e. Four compound plates of an ambulacrum, × 6.
1f. Three plates of an interambulacrum, × 6.
1g. An interambulacrum, × 6.
1h. Tubercle, × 10.
1i. Apical system, × 4.

Orthechinus pretiosus Clark, n. sp. (p. 118).

U. S. Nat. Mus. 146455, type.

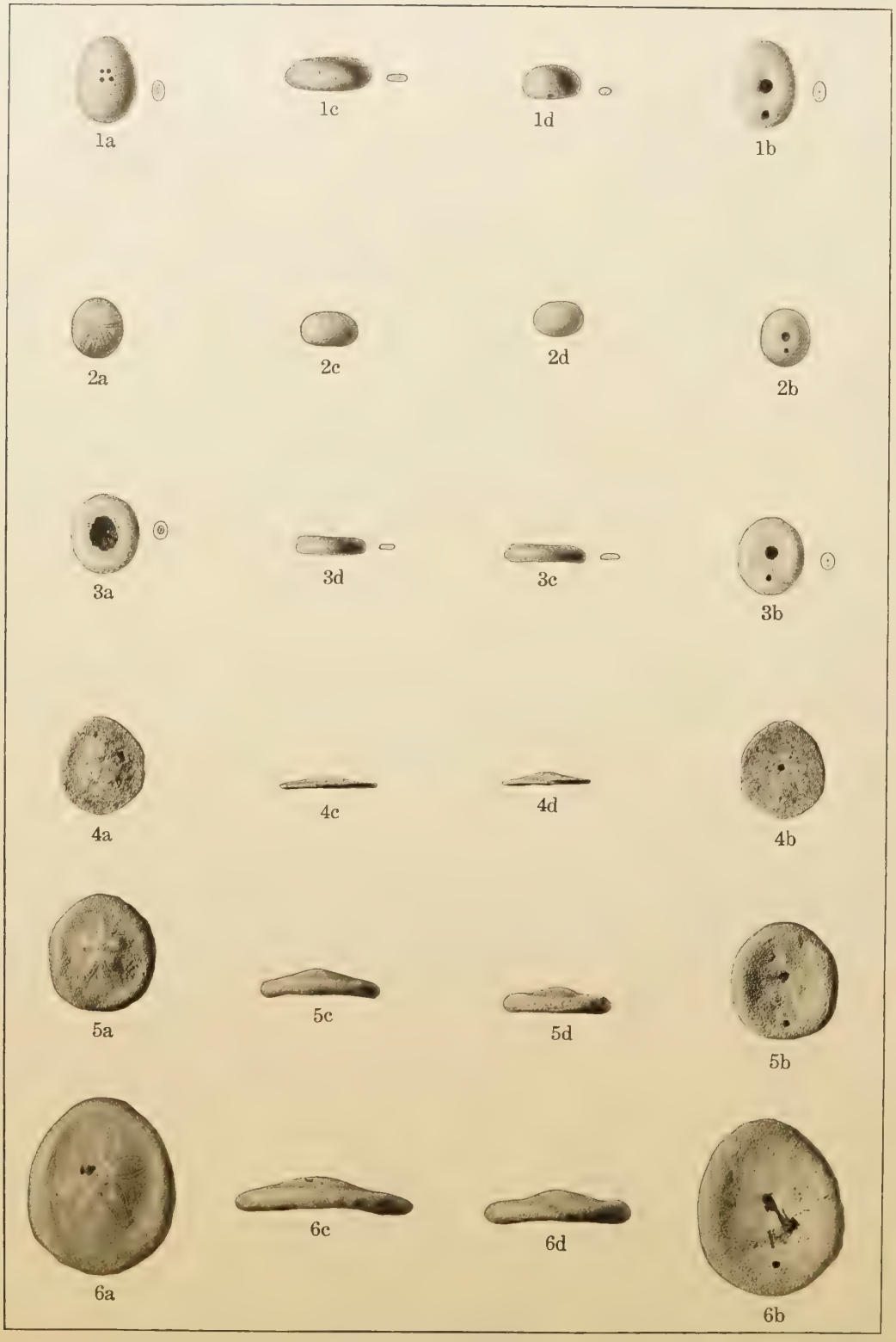
Figure 2a. Upper surface of the test.
2b. Lateral surface of the test.

Echinus (?) sp. (p. 118).

Johns Hopkins Univ. T 2000.

Figure 3. Spines.

39800 15 23



EOCENE ECHINOIDEA.

PLATE LVII.

Echinocyamus huxleyanus Meyer (p. 119).

Johns Hopkins Univ. T 2006.

Figure 1a. Upper surface of the test, × 4.
1b. Lower surface of the test, × 4.
1c. Lateral surface of the test, × 4.
1d. Posterior surface of the test, × 4.

Echinocyamus texanus Twitchell, n. sp. (p. 120).

Johns Hopkins Univ. T 2002, type.

Figure 2a. Upper surface of the test, × 2.
2b. Lower surface of the test, × 2.
2c. Lateral surface of the test, × 2.
2d. Posterior surface of the test, × 2.

Fibularia meridionalis (Meyer) (p. 121).

Johns Hopkins Univ. T 2005.

Figure 3a. Upper surface of the test, × 4½.
3b. Lower surface of the test, × 4½.
3c. Lateral surface of the test, × 4½.
3d. Posterior surface of the test.

Sismondia (?) plana Conrad (p. 121).

Acad. Nat. Sci. Philadelphia 1080, type.

Figure 4a. Upper surface of the test.
4b. Lower surface of the test.
4c. Lateral surface of the test.
4d. Posterior surface of the test.

Laganum (?) crustuloides (Morton) (p. 122).

Boston Soc. Nat. Hist. 8802a, specimen A.

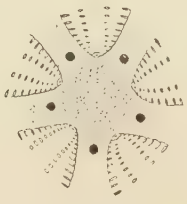
Figure 5a. Upper surface of the test.
5b. Lower surface of the test.
5c. Lateral surface of the test.
5d. Posterior surface of the test.

Laganum (?) crustuloides (Morton) (p. 122).

U. S. Nat. Mus. 164744, specimen B.

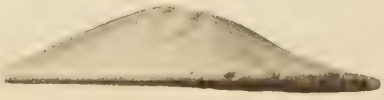
Figure 6a. Upper surface of the test.
6b. Lower surface of the test.
6c. Lateral surface of the test.
6d. Posterior surface of the test.

1a



1c

1d



1e

1b

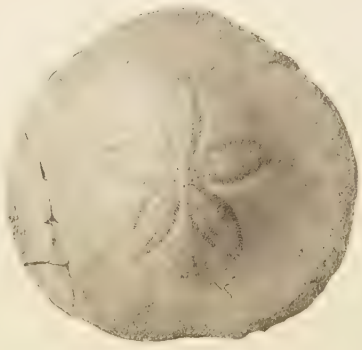
EOCENE ECHINOIDEA.

PLATE LVIII.

PERIARCHUS ALTUS Conrad (p. 130).

Williams College, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Detail of apical system, × 5.
1d. Posterior surface of the test.
1e. Lateral surface of the test.



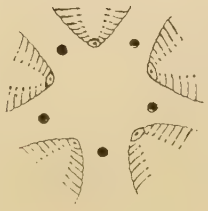
1a

1b

1c

1d

2



1e

1f

PLATE LIX.

SCUTELLA MISSISSIPPIENSIS Twitchell, n. sp. (p. 124).

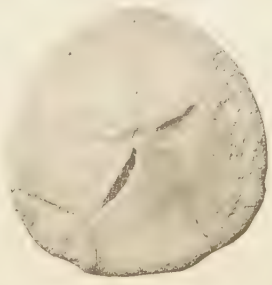
U. S. Nat. Mus. 137655, specimen A, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Posterior surface of the test.
1d. Lateral surface of the test.
1e. Apical system, × 6.
1f. Part of the ambulacra, × 8.

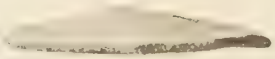
SCUTELLA MISSISSIPPIENSIS Twitchell, n. sp. (p. 124).

U. S. Nat. Mus. 137655a, specimen B.

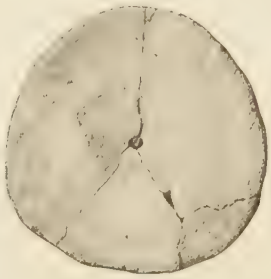
FIGURE 2. Upper surface of the test.



1a



1c

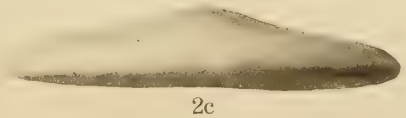


1b

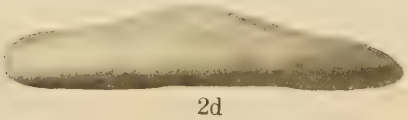
1d

2a

2b



2c



2d

2e

2f

EOCENE ECHINOIDEA.

PLATE LX.

SCUTELLA TUOMEYI Twitchell, n. sp. (p. 125).

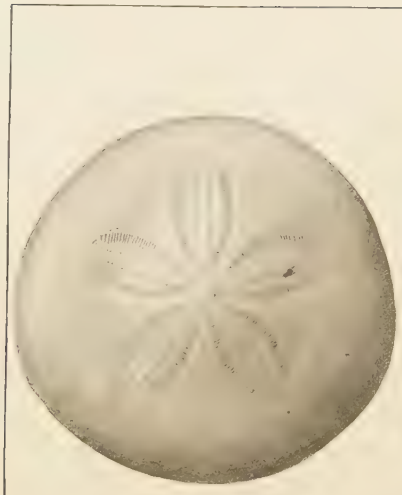
U. S. Nat. Mus. 137970, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.

MORTONELLA QUINQUEFARIA (Say) (p. 128).

U. S. Nat. Mus. 9500, specimen A.

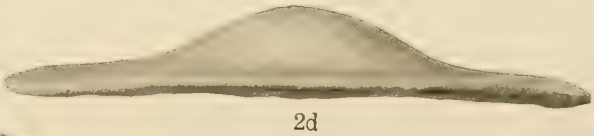
FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Posterior surface of the test.
2d. Lateral surface of the test.
2e. Part of one of the ambulacra, × 4.
2f. Apical system, × 6.



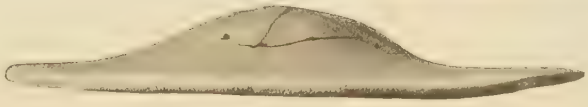
1a

2a

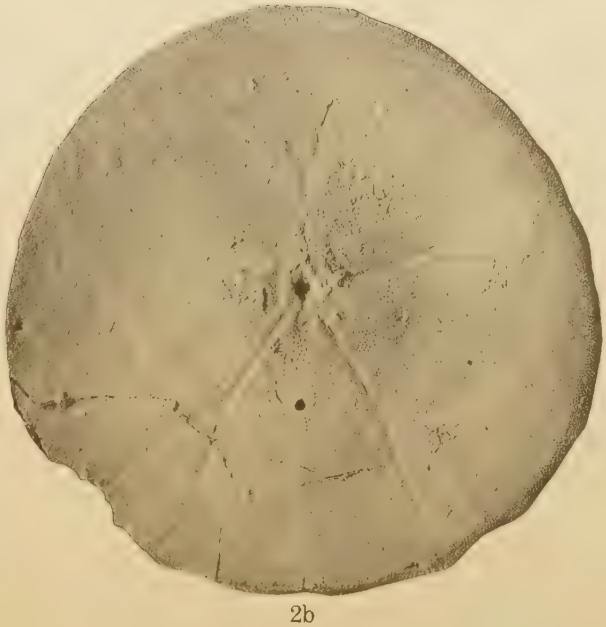
1b



2d

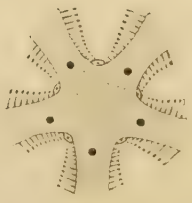


2c



2b

2e



2f

EOCENE ECHINOIDEA.

PLATE LXI.

MORTONELLA QUINQUEFARIA (Say) (p. 128)

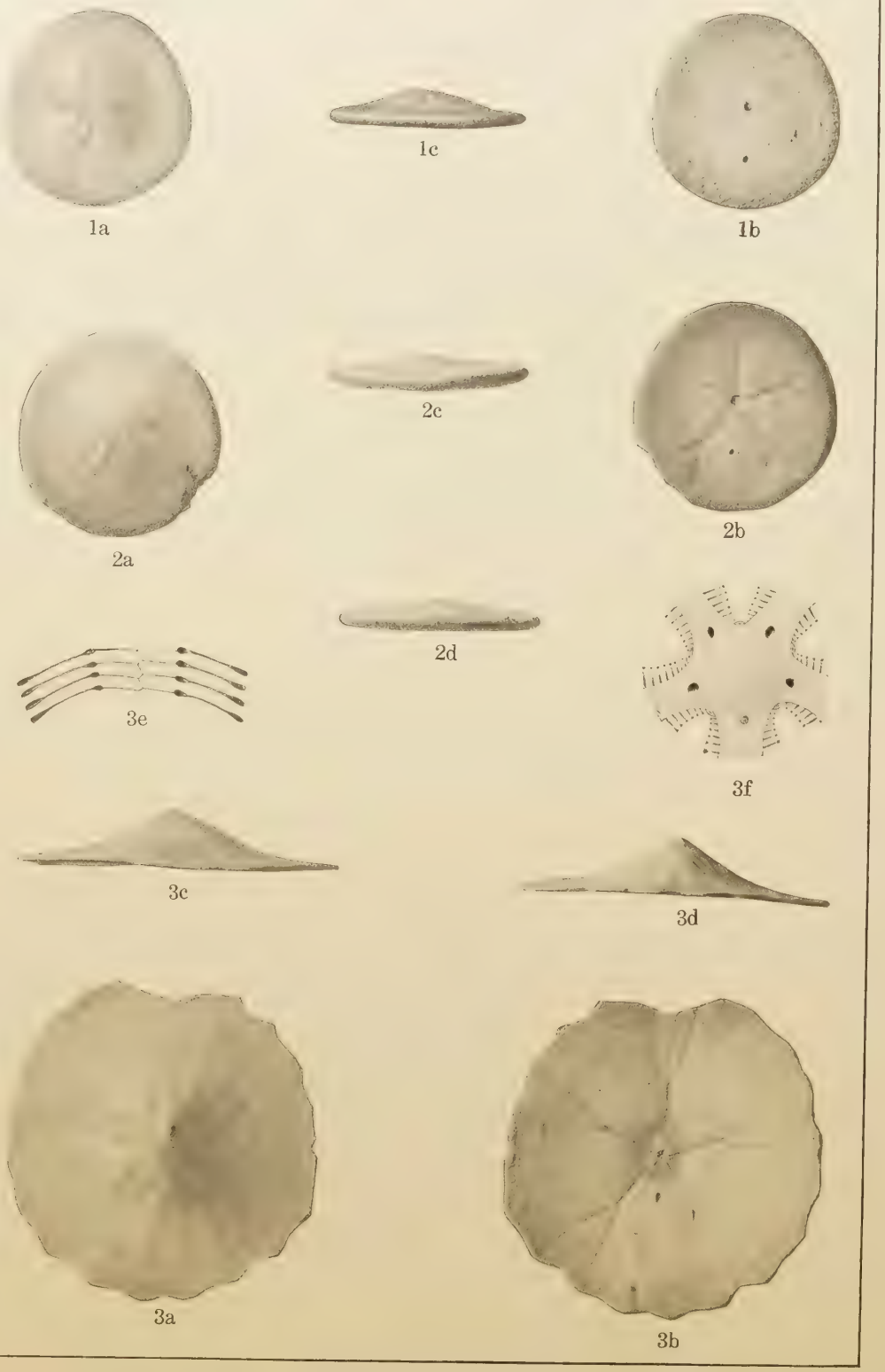
Amherst College, specimen B.

FIGURE 1a. Upper surface of the test.
1b. Lateral surface of the test.

PERIARCHUS LYELLI Conrad (p. 131).

Boston Soc. Nat. Hist. 1553, specimen A.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.
2e. Part of one of the ambulacra, × 5½.
2f. Apical system, × 4.



EOCENE ECHINOIDEA.

PLATE LXII.

Periarchus lyelli Conrad (p. 131).

Johns Hopkins Univ. T 2003, specimen B.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.

Periarchus lyelli Conrad (p. 131).

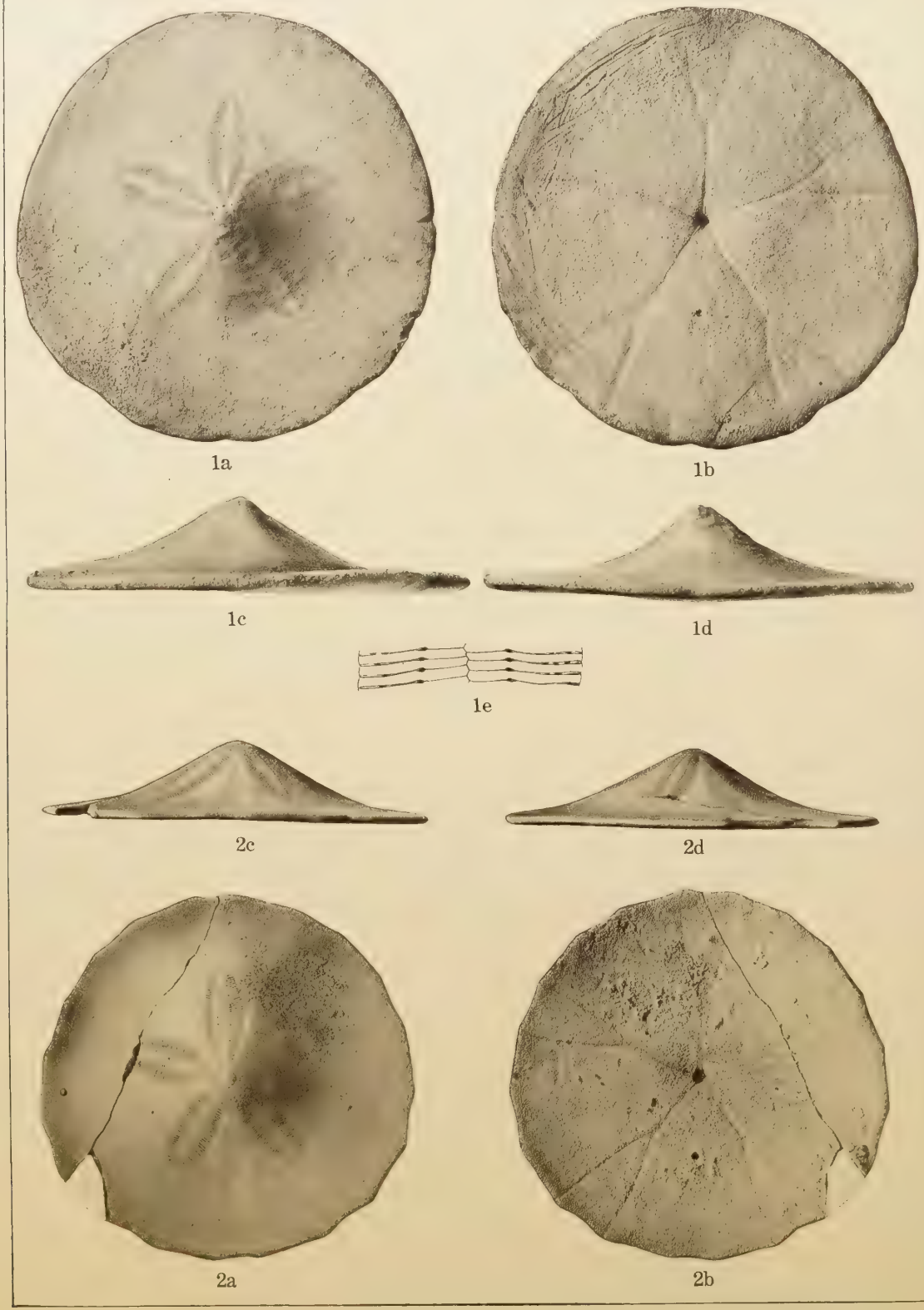
Johns Hopkins Univ. T 2004, specimen C.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.

Periarchus protuberans Twitchell, n. sp. (p. 133).

U. S. Nat. Mus. 164685, type.

Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.
3e. Part of one ambulacrum, × 8.
3f. Apical system, × 8.



1a 1b

1c 1d

1e

2c 2d

2a 2b

EOCENE ECHINOIDEA.

PLATE LXIII.

PERIARCHUS PILEUS-SINENSIS Ravenel (p. 135).

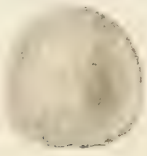
U. S. Nat. Mus. 5133, specimen A.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Part of one ambulacrum, × 6.

PERIARCHUS PILEUS-SINENSIS Ravenel (p. 135).

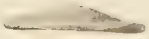
U. S. Nat. Mus. 137791, specimen B.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Posterior surface of the test.
2d. Lateral surface of the test.

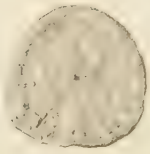


1a

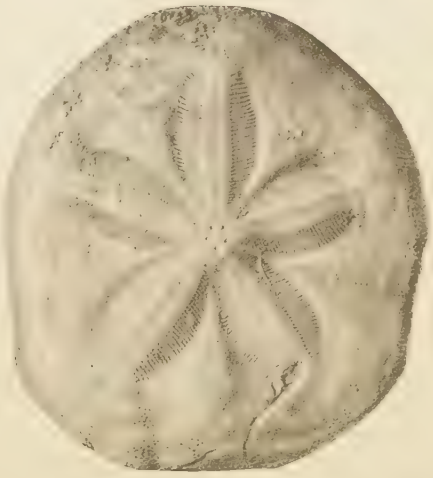
1d



1c



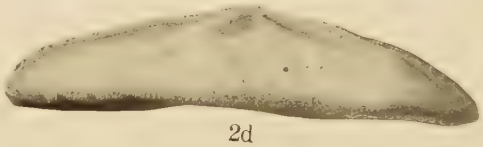
1b



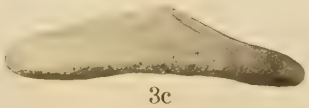
2a

2b

2c



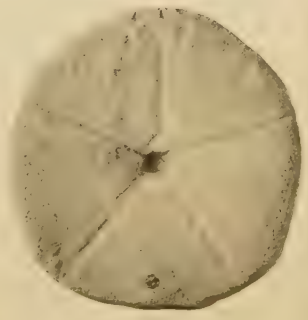
2d



3c

3a

3d



3b

EOCENE ECHINOIDEA.

PLATE LXIV.

SCUTELLA(?) CONRADI (Cotteau) (p. 126).

Acad. Nat. Sci. Philadelphia 1081, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.

CLYPEASTER ROGERSI Morton (p. 136).

U. S. Nat. Mus. 137801, specimen A.

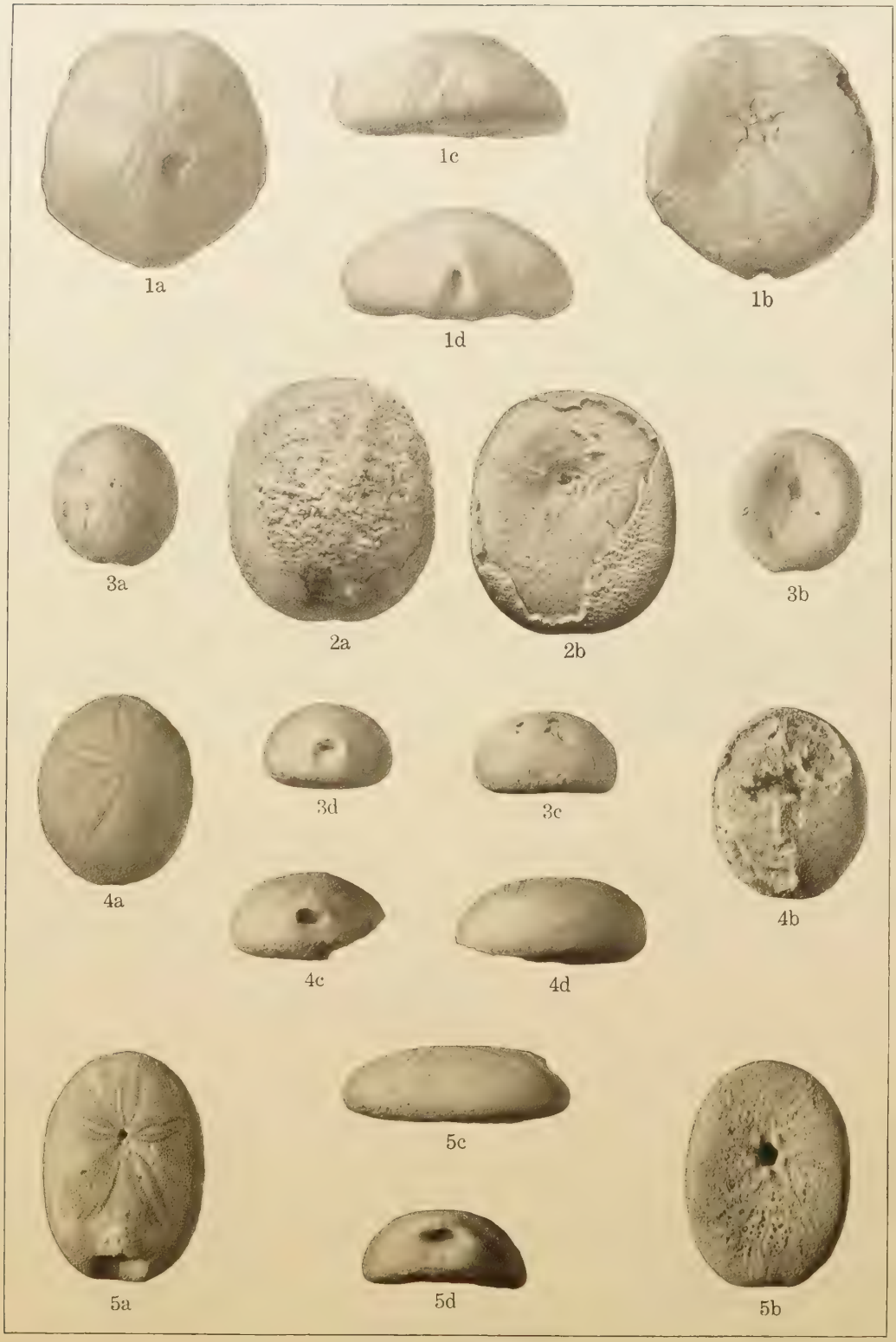
FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Posterior surface of the the test.
2d. Lateral surface of the test.

CLYPEASTER ROGERSI Morton (p. 136).

U. S. Nat. Mus. 155377, specimen B.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.

39800°—15——24



EOCENE ECHINOIDEA.

PLATE LXV.

ECHINANTHUS GEORGIENSIS Twitchell, n. sp. (p. 139).

U. S. Nat. Mus. 165683b, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.

CASSIDULUS CALIFORNICUS F. M. Anderson (p. 140).

U. S. Nat. Mus. 165664.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.

CASSIDULUS (RHYNCHOPYGUS?) HOLMESI Twitchell, n. sp. (p. 140).

Am. Mus. Nat. Hist., type.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.

CASSIDULUS (RHYNCHOPYGUS) LYELLI (Conrad) (p. 141).

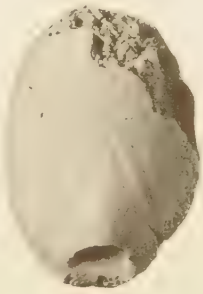
Boston Soc. Nat. Hist. 1552a.

FIGURE 4a. Upper surface of the test.
4b. Lower surface of the test.
4c. Posterior surface of the test.
4d. Lateral surface of the test.

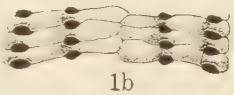
CASSIDULUS (RHYNCHOPYGUS) RAVENELI Twitchell, n. sp. (p. 142).

Am. Mus. Nat. Hist., specimen A, type.

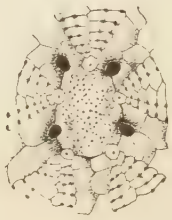
FIGURE 5a. Upper surface of the test.
5b. Lower surface of the test.
5c. Lateral surface of the test.
5d. Posterior surface of the test.



1a



1b

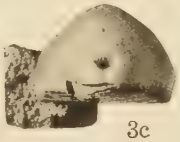


1c

2b

2a

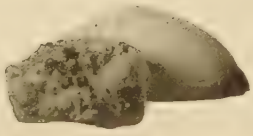
3a



3c

3b

4e

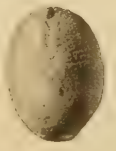


3d

4b

5a

5b



4a

4c

4d

EOCENE ECHINOIDEA.

PLATE LXVI.

CASSIDULUS (RHYNCHOPYGUS) RAVENELI Twitchell, n. sp. (p. 142).

Am. Mus. Nat. Hist., specimen B.

FIGURE 1a. Upper surface of the test.
1b. Part of one ambulacrum, × 8.
1c. Apical system, × 8.

CASSIDULUS (RHYNCHOPYGUS) RAVENELI Twitchell, n. sp. (p. 142).

Am. Mus. Nat. Hist., specimen C.

FIGURE 2a. Lower surface of the test.
2b. Part of floscelle, × 4.

CASSIDULUS (RHYNCHOPYGUS?) PATELLIFORMIS (Bouvé) (p. 143).

Boston Soc. Nat. Hist. 1558, type.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Posterior surface of the test.
3d. Lateral surface of the test.

CASSIDULUS (RHYNCHOPYGUS) DEPRESSUS Twitchell, n. sp. (p. 144).

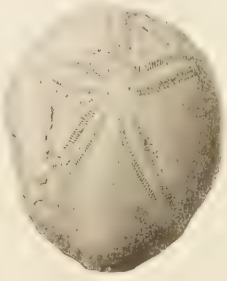
Boston Soc. Nat. Hist. 1557a, specimen A, type.

FIGURE 4a. Upper surface of the test.
4b. Lower surface of the test.
4c. Posterior surface of the test.
4d. Lateral surface of the test.
4e. Part of one ambulacrum, × 12.

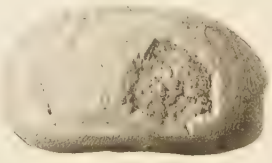
CASSIDULUS (RHYNCHOPYGUS) DEPRESSUS Twitchell, n. sp. (p. 144).

Boston Soc. Nat. Hist. 1557b, specimen B.

FIGURE 5a. Lower surface of the test.
5b. Part of floscelle, × 8.

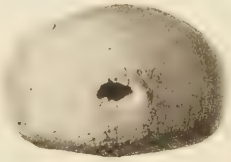


1a

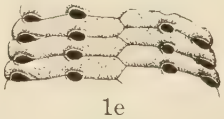


1d

1b

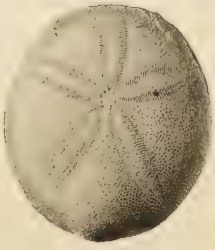


1c

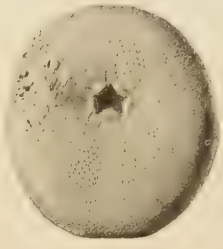


1e

1f



2a

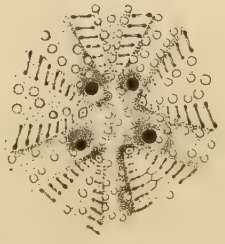


2b

2c

2d

2e



2g

2f

EOCENE ECHINOIDEA.

PLATE LXVII.

CASSIDULUS (PYGORHYNCHUS) CONRADI Conrad (p. 145).

Acad. Nat. Sci. Philadelphia 1078, probably type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Posterior surface of the test.
1d. Lateral surface of the test.
1e. Part of one ambulacrum, × 8.
1f. Part of floscelle, × 7.

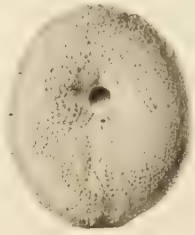
CASSIDULUS (PYGORHYNCHUS) CAROLINENSIS Twitchell, n. sp. (p. 146).

Johns Hopkins Univ. T 2004, type.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.
2e. Part of floscelle, × 5.
2f. Part of one ambulacrum, × 8½.
2g. Apical system, × 6.

1a

1c



1b

1d

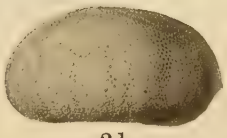
1f

1e

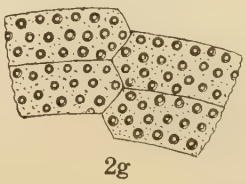
2a

2c

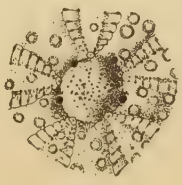
2b



2d



2g



2f

2e

2h

EOCENE ECHINOIDEA.

PLATE LXVIII.

BREYNELLA GREGORYI Twitchell, n. sp. (p. 148).

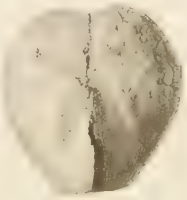
Am. Mus. Nat. Hist., type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Posterior surface of the test.
1d. Lateral surface of the test.
1e. Apical system, × 6.
1f. Part of ambulacra.

ECHINOLAMPAS APPENDICULATUS Emmons (p. 149).

U. S. Nat. Mus. 138017.

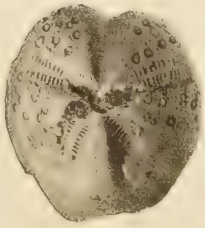
FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Posterior surface of the test.
2d. Lateral surface of the test.
2e. Part of floscelle, × 4.
2f. Apical system, × 5.
2g. Part of interambulacra.
2h. Part of ambulacra, × 10.



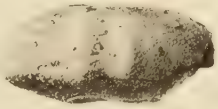
1a

1b

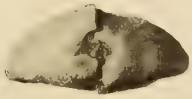
1c



2a



2b



1d

3a

3b

PLATE LXIX.

HEMIPATAGUS ARGUTUS Clark, n. sp. (p. 150).

U. S. Nat. Mus. 141107, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.

HEMIPATAGUS SUBROSTRATUS Clark, n. sp. (p. 151).

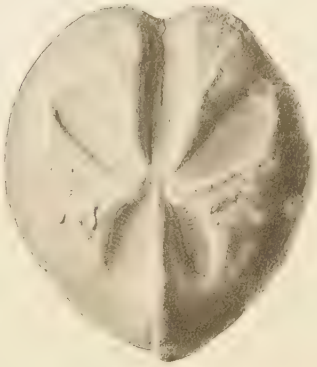
U. S. Nat. Mus. 164652, type.

FIGURE 2a. Upper surface of the test.
2b. Anterior surface of the test.

SCHIZASTER LECONTEI Merriam (p. 151).

Univ. of California, type.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.

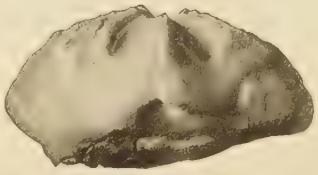


1a

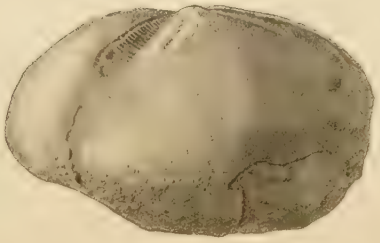
1b

2

1c

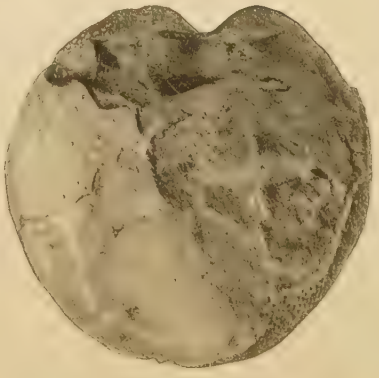


1d



3c

3a



3b

EOCENE ECHINOIDEA.

PLATE LXX.

SCHIZASTER ARMIGER Clark, n. sp. (p. 152).

U. S. Nat. Mus. 141104, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.

SCHIZASTER sp. (p. 152).

Johns Hopkins Univ. T 2001.

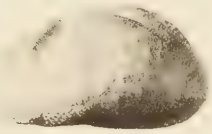
FIGURE 2. Fragment of the test showing portion of ambulacrum with adjacent interambulacrum.

LINTHIA WILMINGTONENSIS Clark, n. sp. (p. 152).

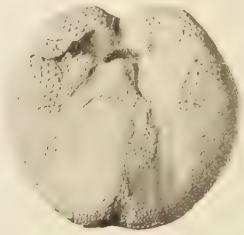
U. S. Nat. Mus. 166482, type.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.

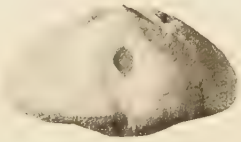
1a



1c



1b

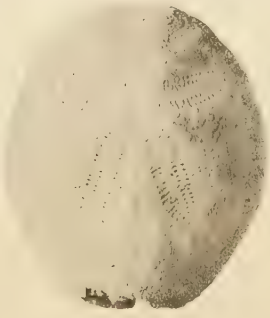


1d

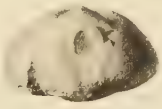
2a

2c

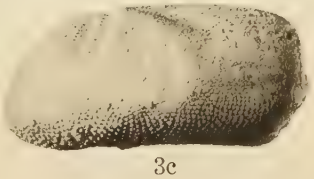
2b



3a

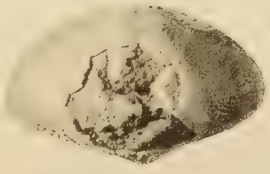


2d

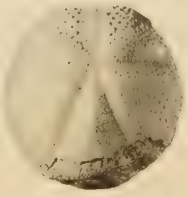


3c

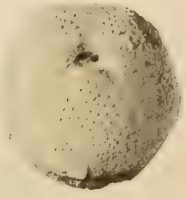
3b



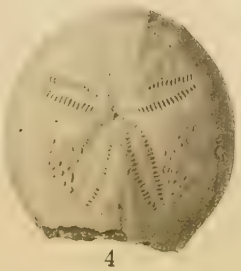
3d



5a

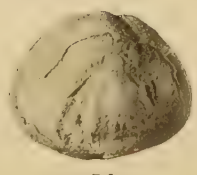


5b



4

5c



5d

EOCENE ECHINOIDEA.

PLATE LXXI.

LINTHIA ALABAMENSIS Clark, n. sp. (p. 153).

U. S. Nat. Mus. 173371, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test

LINTHIA ALABAMENSIS Clark, n. sp. (p. 153).

U. S. Nat. Mus. 166483.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.

EUPATAGUS CAROLINENSIS Clark, n. sp. (p. 153).

U. S. Nat. Mus. 166484, type.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.

EUPATAGUS CAROLINENSIS Clark, n. sp. (p. 153).

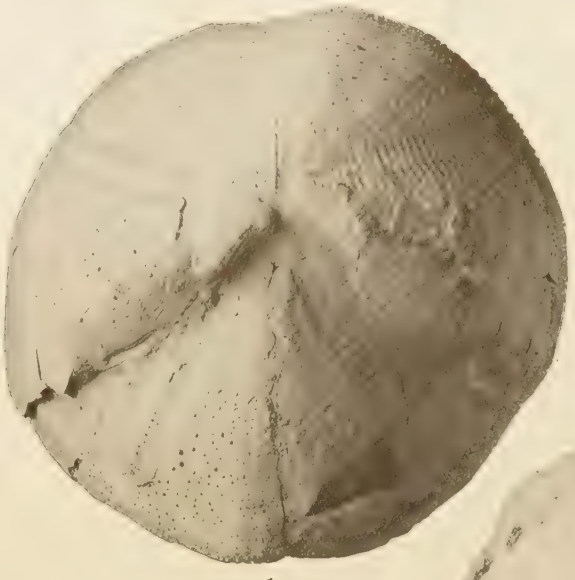
U. S. Nat. Mus. 164674.

FIGURE 4. Upper surface of the test.

MACROPNEUSTES CAROLINENSIS Clark, n. sp. (p. 154).

U. S. Nat. Mus. 164651, type.

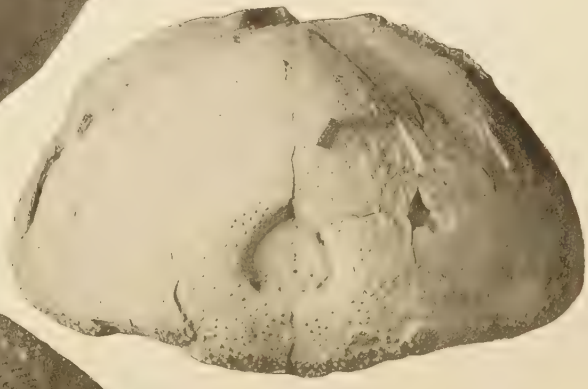
FIGURE 5a. Upper surface of the test.
5b. Lower surface of the test.
5c. Lateral surface of the test.
5d. Posterior surface of the test.



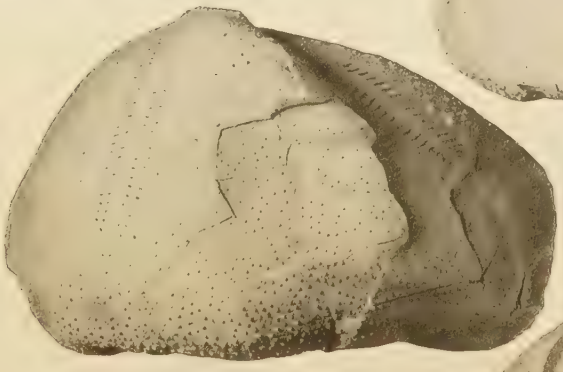
1a

2a

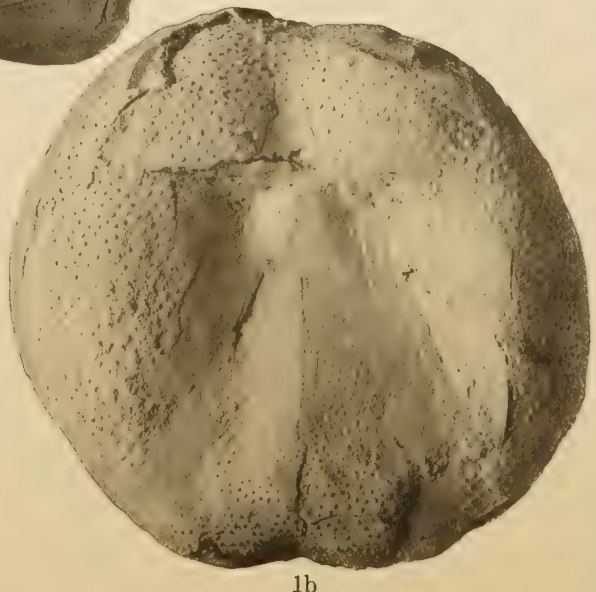
2b



1d



1c



1b

2c

2d

EOCENE ECHINOIDEA.

PLATE LXXII.

MACROPNEUSTES MORTONI (Conrad) (p. 155).

U. S. Nat. Mus. 146468.

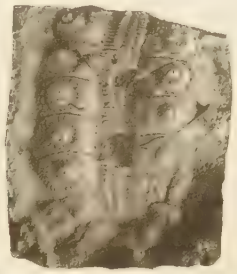
FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.

SARSELLA GREGORYI Clark, n. sp. (p. 155).

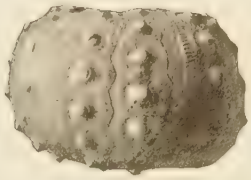
Am. Mus. Nat. Hist., type.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.

39800—15—25

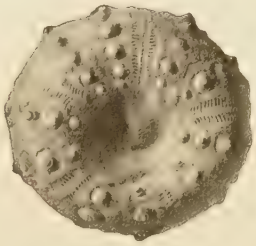


1



2c

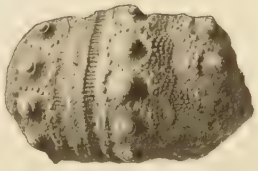
2b



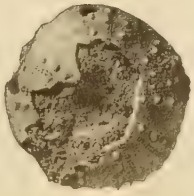
2a

3

5



4



7a

6b

7b

8a

8b

6a

7c

OLIGOCENE ECHINOIDEA.

PLATE LXXIII.

CIDARIS MORTONI Conrad (p. 157).

Boston Soc. Nat. Hist. 1555.

FIGURE 1. Portion of test.

CIDARIS SMITHI Clark, n. sp. (p. 157).

Alabama Geol. Survey, type.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.

CIDARIS SMITHI Clark, n. sp. (p. 157).

Alabama Geol. Survey.

FIGURE 3. Spine.

CIDARIS GEORGIANA Clark, n. sp. (p. 158).

U. S. Nat. Mus. 166485, type.

FIGURE 4. Portion of the test.

CIDARIS BRANNERI Arnold (p. 158).

Leland Stanford Junior Univ. 1056, type.

FIGURE 5. Spine.

CŒLOPLEURUS ALDRICHI Clark, n. sp. (p. 158)

U. S. Nat. Mus. (Aldrich), type.

FIGURE 6a. Upper surface of the test.
6b. Lateral surface of the test.

CŒLOPLEURUS ALDRICHI Clark, n. sp. (p. 158).

U. S. Nat. Mus. (Aldrich).

FIGURE 7a. Upper surface of the test.
7b. Lower surface of the test.
7c. Lateral surface of the test.

GAGARIA AMERICANA Clark, n. sp. (p. 159).

U. S. Nat. Mus. (Aldrich), type.

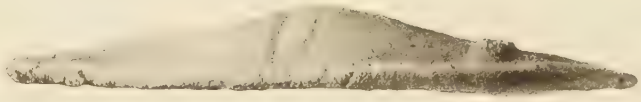
FIGURE 8a. Upper surface of the test.
8b. Lateral surface of the test.

1a

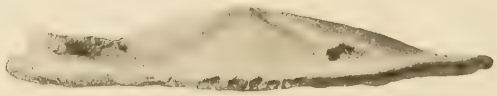
1b

1c

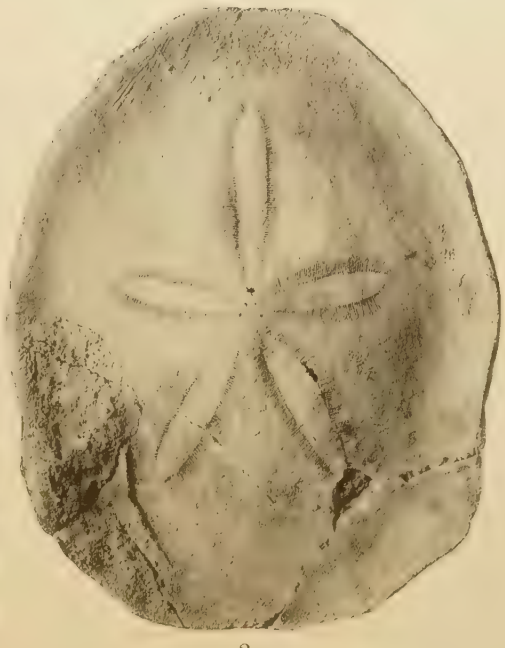
1d



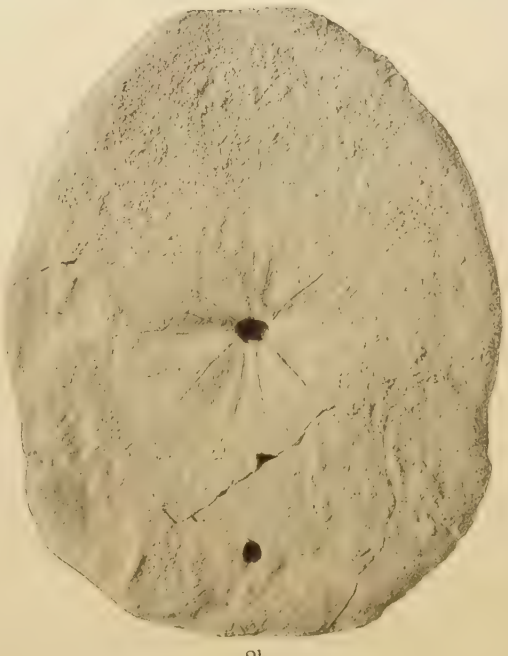
2c



2d



2a



2b

OLIGOCENE ECHINOIDEA.

PLATE LXXIV.

ECHINOCYAMUS VAUGHANI Twitchell, n. sp. (p. 160).

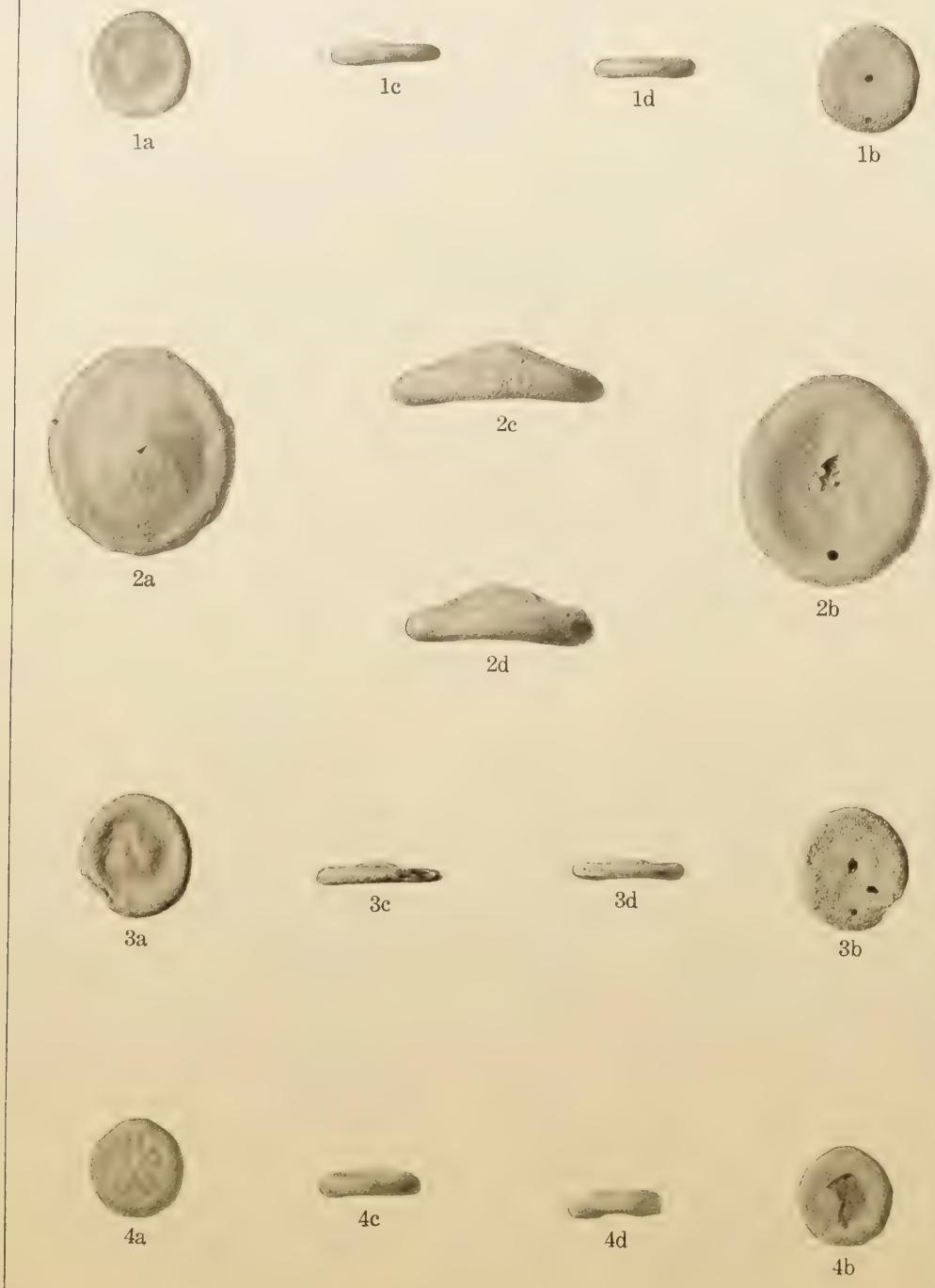
U. S. Nat. Mus. 166486, type.

FIGURE 1a. Upper surface of the test, × 2.
1b. Lower surface of the test, × 2.
1c. Lateral surface of the test, × 2.
1d. Posterior surface of the test, × 2.

LAGANUM ELDRIDGEI Twitchell, n. sp. (p. 160).

U. S. Nat. Mus. 164683, type.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior of the test.



OLIGOCENE ECHINOIDEA.

PLATE LXXV.

LAGANUM ARCHERENSIS Twitchell, n. sp. (p. 161).

U. S. Nat. Mus. 164667a, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.

LAGANUM JOHNSONI Twitchell, n. sp. (p. 162).

U. S. Nat. Mus. 137202, type.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.

LAGANUM FLORIDANUM Twitchell, n. sp. (p. 163)

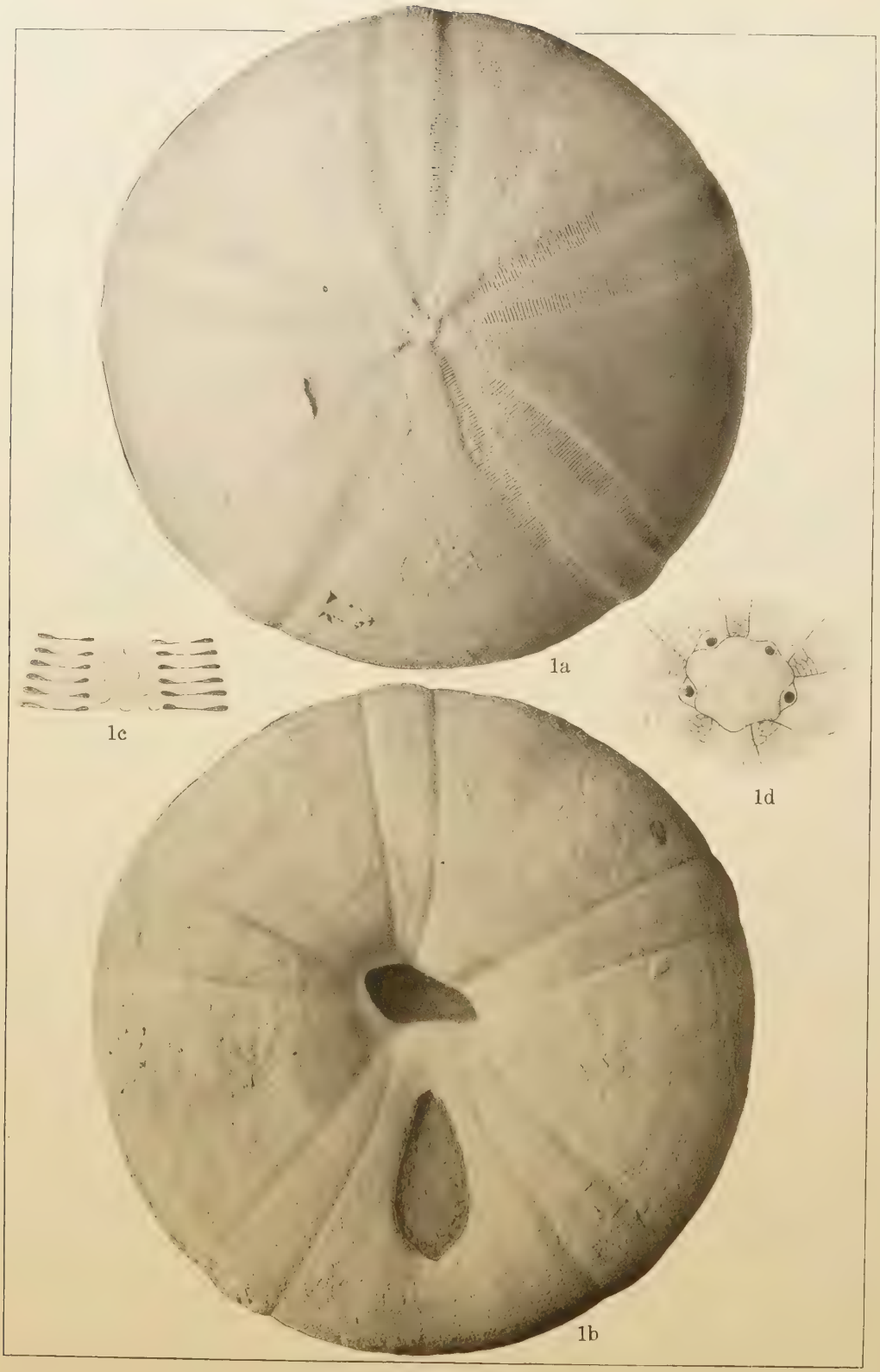
U. S. Nat. Mus. 137884, type.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.

LAGANUM DALLI Twitchell, n. sp. (p. 164).

U. S. Nat. Mus. 164667b, type.

FIGURE 4a. Upper surface of the test.
4b. Lower surface of the test.
4c. Lateral surface of the test.
4d. Posterior surface of the test.



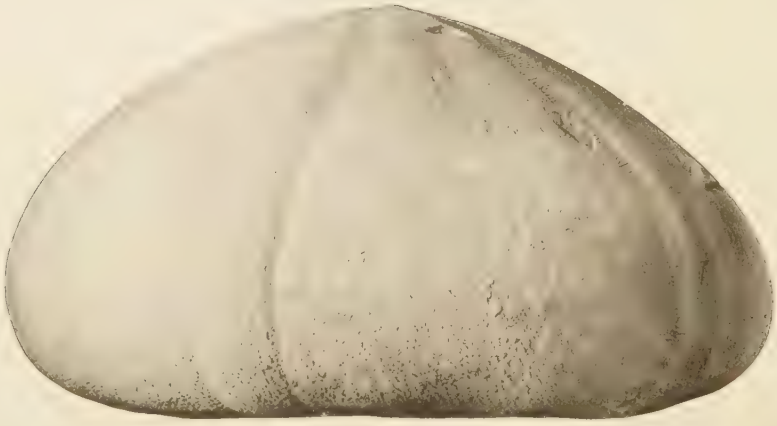
OLIGOCENE ECHINOIDEA.

PLATE LXXVI.

AMBLYPYGUS MERRILLI Twitchell, n. sp. (p. 165).

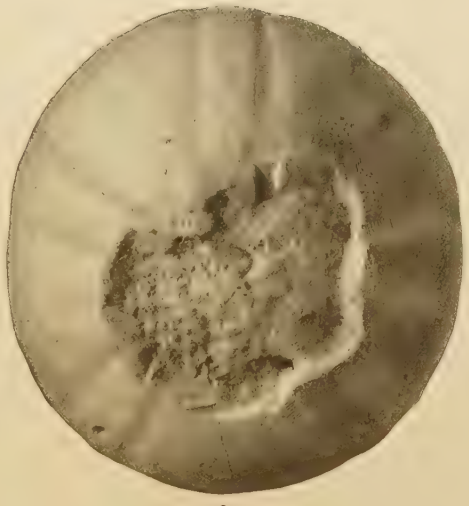
U. S. Nat. Mus. 164934, specimen A, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Part of one ambulacrum, × 3
1d. Apical system, × 3.

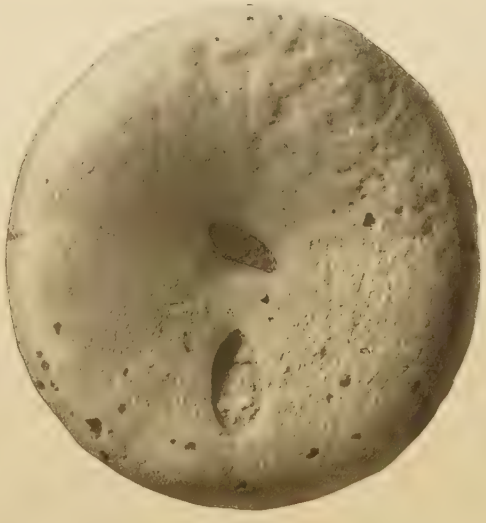


1a

1b



2a



2b

OLIGOCENE ECHINOIDEA.

PLATE LXXVII.

AMBLYPYGUS MERRILLI Twitchell, n. sp. (p. 165).

U. S. Nat. Mus. 164934, specimen A.

FIGURE 1a. Lateral surface of the test.
1b. Posterior surface of the test.

AMBLYPYGUS MERRILLI Twitchell, n. sp. (p. 165).

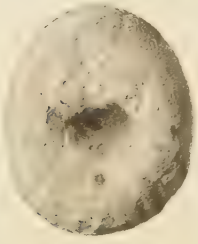
U. S. Nat. Mus. 137870, specimen B.

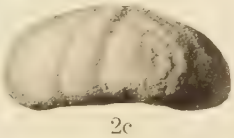
FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.

1a

1b

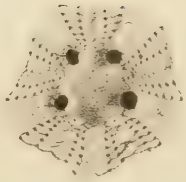
2a


2b

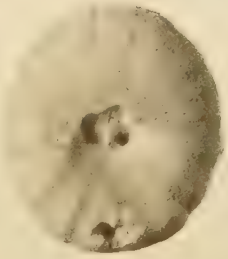

2c

2d

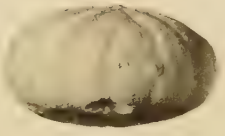
3a


3b

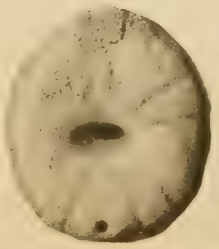
4a


4b

4c


4d

5c


5b

5d

5a

OLIGOCENE ECHINOIDEA.

PLATE LXXVIII.

AMBLYPYGUS MERRILLI Twitchell, n. sp. (p. 165).

U. S. Nat. Mus. 137870, specimen B.

FIGURE 1a. Lateral surface of the test.
1b. Posterior surface of the test.

OLIGOPYGUS WETHERBYI De Loriol (p. 166).

U. S. Nat. Mus. 137881a, specimen A.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.

OLIGOPYGUS WETHERBYI De Loriol (p. 166).

U. S. Nat. Mus. 137881b, specimen B.

FIGURE 3a. Part of one ambulacrum, × 8.
3b. Apical system, × 5.

OLIGOPYGUS HALDERMANI (Conrad) (p. 167).

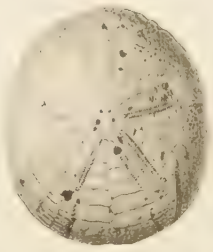
U. S. Nat. Mus. 112506, specimen A.

FIGURE 4a. Upper surface of the test.
4b. Lower surface of the test.
4c. Lateral surface of the test.
4d. Posterior surface of the test.

OLIGOPYGUS HALDERMANI (Conrad) (p. 167).

U. S. Nat. Mus. 164661, specimen B.

FIGURE 5a. Upper surface of the test.
5b. Lower surface of the test.
5c. Lateral surface of the test.
5d. Posterior surface of the test.

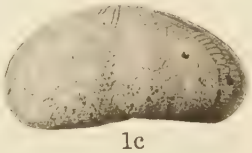


1a

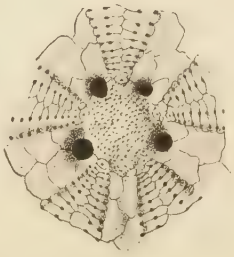
1d

1b

1f

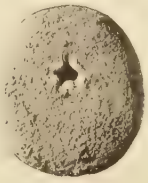


1c



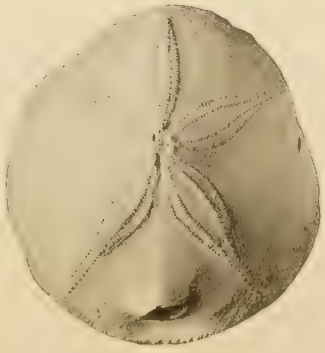
1e

2a

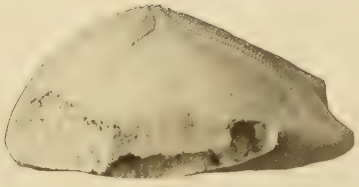


2b

2c



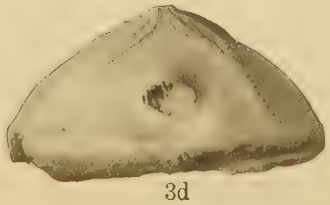
3a



3c

2d

3b



3d

OLIGOCENE ECHINOIDEA.

PLATE LXXIX.

Oligopygus floridanus Twitchell, n. sp. (p. 169).

U. S. Nat. Mus. 164660, type.

Figure 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Apical system, × 4½.
1f. Part of one ambulacrum. × 10.

Cassidulus (Pygorhynchus) georgiensis Twitchell, n. sp. (p. 170).

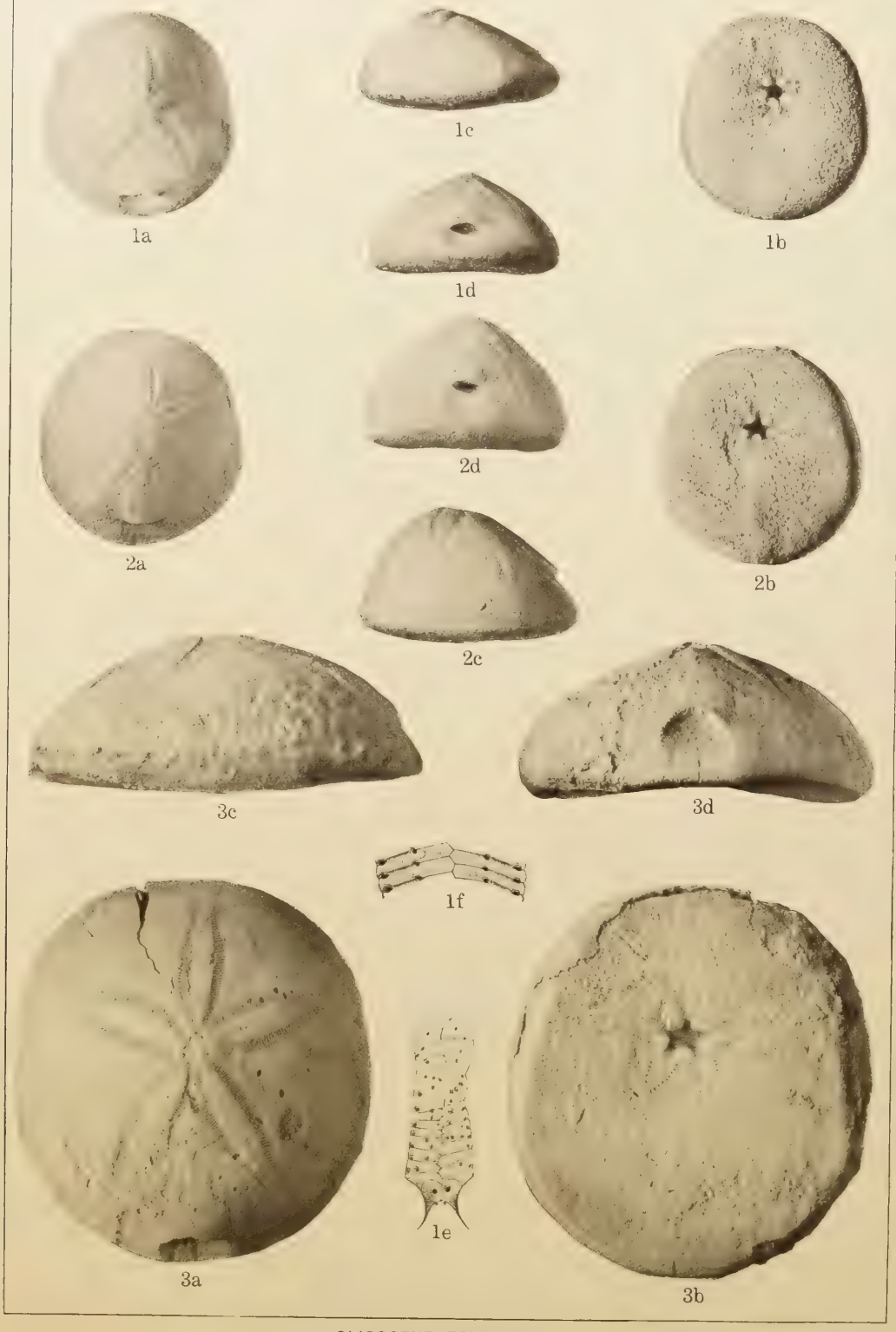
U. S. Nat. Mus. 164347, type.

Figure 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.

Cassidulus (Pygorhynchus) gouldii (Bouvé) (p. 171).

Boston Soc. Nat. Hist. 1756, specimen A, type.

Figure 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.



OLIGOCENE ECHINOIDEA.

PLATE LXXX.

CASSIDULUS (PYGORHYNCHUS) GOULDII (Bouvé) (p. 171).

U. S. Nat. Mus. 137904, specimen B.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e Part of floscelle, × 5.
1f. Part of one ambulacrum. × 5½.

CASSIDULUS (PYGORHYNCHUS) GOULDII (Bouvé) (p. 171).

U. S. Nat. Mus. 137904a, specimen C.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.

CASSIDULUS (PYGORHYNCHUS) ALABAMENSIS Twitchell, n. sp. (p. 172).

Johns Hopkins Univ., type.

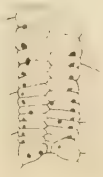
FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.

1a

1b

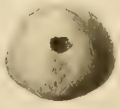
3a

3b

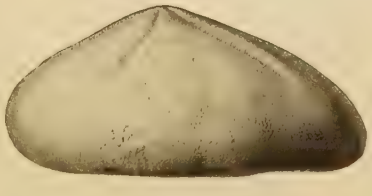


2

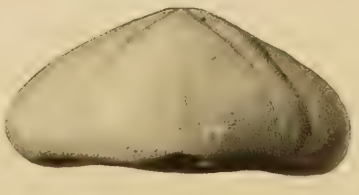
3c



3d



1c



1d

OLIGOCENE ECHINOIDEA.

PLATE LXXXI.

ECHINOLAMPAS ALDRICHI Twitchell, n. sp. (p. 173).

Johns Hopkins Univ. T 1099, specimen A, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.

ECHINOLAMPAS ALDRICHI Twitchell, n. sp. (p. 173).

Johns Hopkins Univ. T 1099.

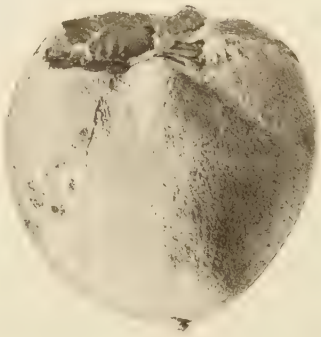
FIGURE 2. Part of floscelle. × 4½.

AGASSIZIA CONRADI (Bouvé) (p. 174).

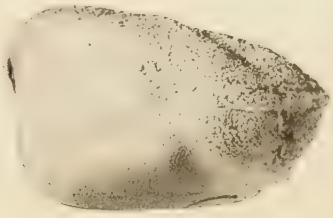
U. S. Nat. Mus. 164744.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.

1a



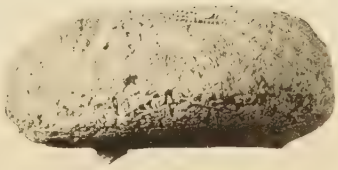
1b



1c

2a

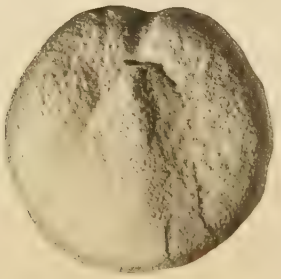
2b



2c

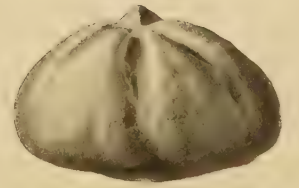
3a

2d



3b

3c



3d

PLATE LXXXII.

SCHIZASTER FLORIDANUS Clark, n. sp. (p. 175).

U. S. Nat. Mus. 164655, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.

EUPATAGUS FLORIDANUS Clark, n. sp. (p. 176).

U. S. Nat. Mus. 137881, type.

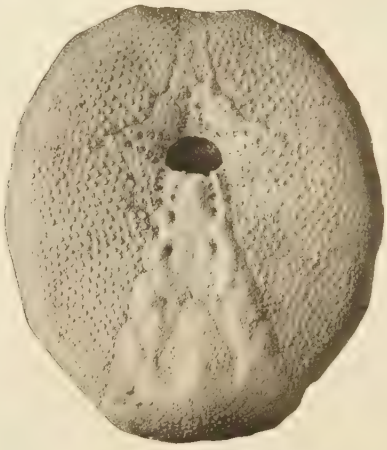
FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.

SCHIZASTER AMERICANA Clark, n. sp. (p. 176).

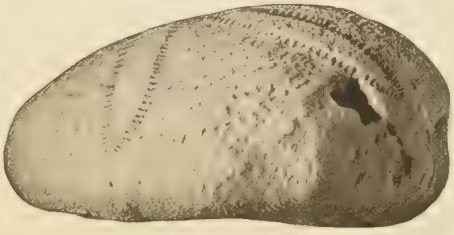
U. S. Nat. Mus. 165695, type.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Anterior surface of the test.

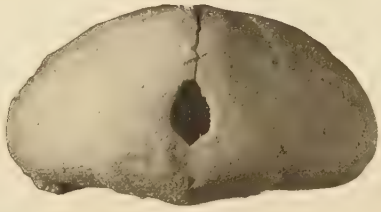
1a



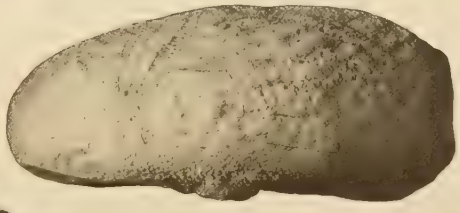
1b



1c

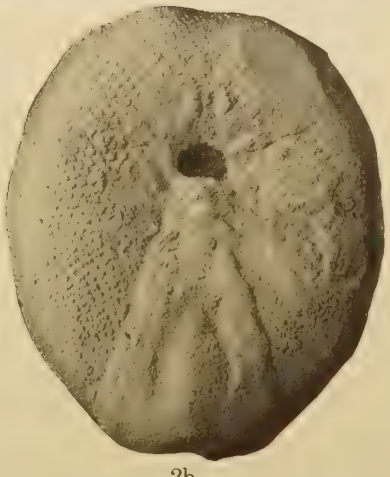


2d



2c

2a



2b

OLIGOCENE ECHINOIDEA.

PLATE LXXXIII.

EUPATAGUS FLORIDANUS Clark, n. sp. (p. 176).

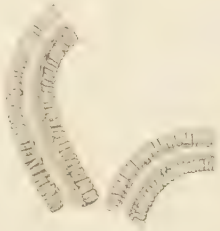
Wagner Free Inst. Sci., specimen B.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.

EUPATAGUS FLORIDANUS Clark, n. sp. (p. 176).

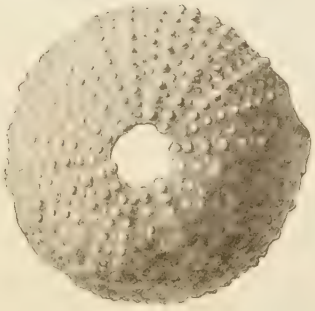
Mus. Comp. Zool., specimen C.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.



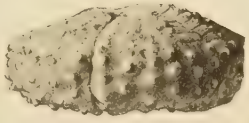
1

2

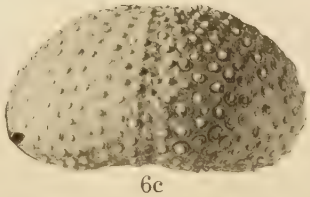


6a

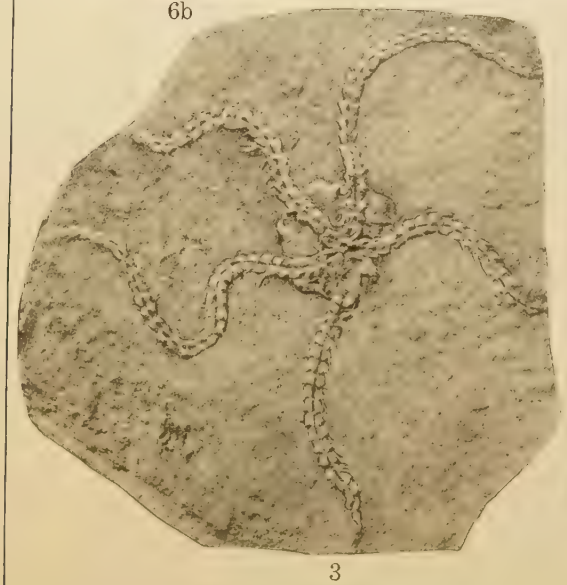
6b



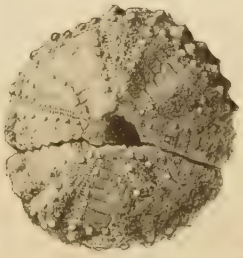
4c



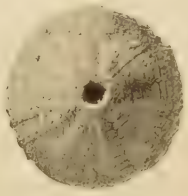
6c



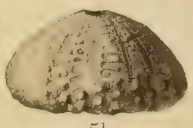
3



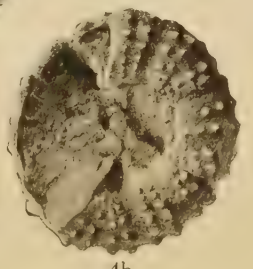
4a



5a



5b



4b

MIOCENE STELLEROIDEA AND ECHINOIDEA.

PLATE LXXXIV.

OPHIODERMA (?) sp. (p. 178).

Johns Hopkins Univ. T 1000.

FIGURE 1. Fragment of arms.

AMPHIURA SANCTÆCRUCIS Arnold (p. 178).

Stanford Univ. 1078, type.

FIGURE 2. Cast of dorsal surface, × 3.

AMPHIURA SANCTÆCRUCIS Arnold (p. 178).

U. S. Nat. Mus. 165431, type.

FIGURE 3. Cast of ventral surface.

CŒLOPLEURUS IMPROCERUS (Conrad) (p. 180).

U. S. Nat. Mus. 166487.

FIGURE 4a. Upper surface of the test.
4b. Lower surface of the test.
4c. Lateral surface of the test.

CŒLOPLEURUS SLOANI Clark, n. sp. (p. 181).

U. S. Nat. Mus. 166488, type.

FIGURE 5a. Upper surface of the test.
5b. Lateral surface of the test.

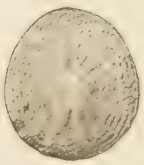
PSAMMECHINUS PHILANTHROPUS (Conrad) (p. 181).

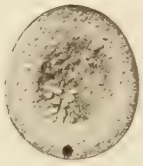
Johns Hopkins Univ. T 1001.

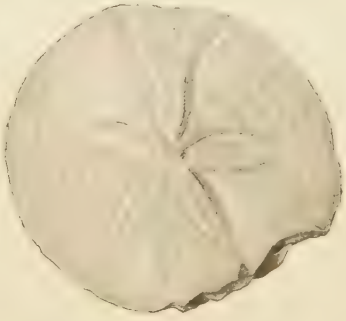
FIGURE 6a. Upper surface of the test.
6b. Lower surface of the test.
6c. Lateral surface of the test.

1a

1b

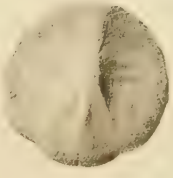

2a


2b


4

2c

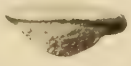
5

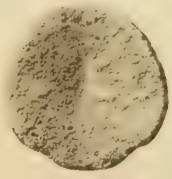

3a

6

7a

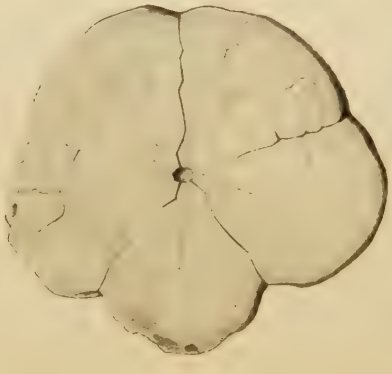
8a


8b


3b

7b

3c


9

3d

7c

MIOCENE ECHINOIDEA.

PLATE LXXXV.

SISMONDIA (?) ARNOLDI Twitchell, n. sp. (p. 182).

U. S. Nat. Mus. 165538, type.

FIGURE 1a. Upper surface of the test, × 2.
1b. Lower surface of the test, × 2.

SISMONDIA (?) COALINGAENSIS Twitchell, n. sp. (p. 183).

U. S. Nat. Mus. 165717, type.

FIGURE 2a. Upper surface of the test, × 2.
2b. Lower surface of the test, × 2.
2c. Lateral surface of the test, × 2.

SCUTELLA ANDERSONI Twitchell, n. sp. (p. 183).

U. S. Nat. Mus. 165719, type.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.

SCUTELLA FAIRBANKSI Pack (p. 184).

Univ. California, specimen A, type.

FIGURE 4. Upper surface of the test.

SCUTELLA FAIRBANKSI Pack (p. 184).

U. S. Nat. Mus. 164963, specimen B.

FIGURE 5. Upper surface of the test.

SCUTELLA FAIRBANKSI Pack (p. 184).

U. S. Nat. Mus. 164963, specimen C.

FIGURE 6. Upper surface of the test, × 1½.

SCUTELLA (?) MERRIAMI (Anderson) (p. 185).

U. S. Nat. Mus. 165716, specimen A.

FIGURE 7a. Upper surface of the test, × 2.
7b. Lower surface of the test, × 2.
7c. Lateral surface of the test.

SCUTELLA (?) MERRIAMI (Anderson) (p. 185).

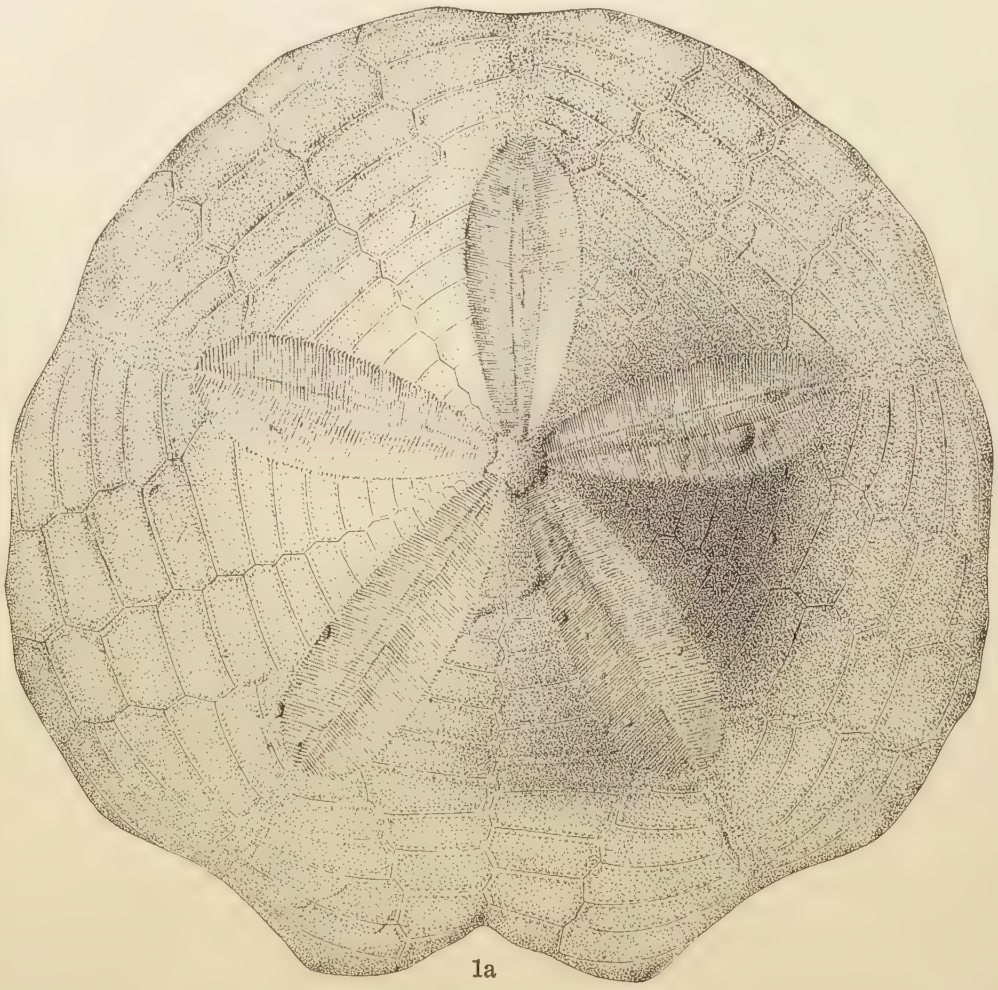
U. S. Nat. Mus. 165584, specimen B.

FIGURE 8a. Upper surface of the test, × 2.
8b. Lower surface of the test, × 2.

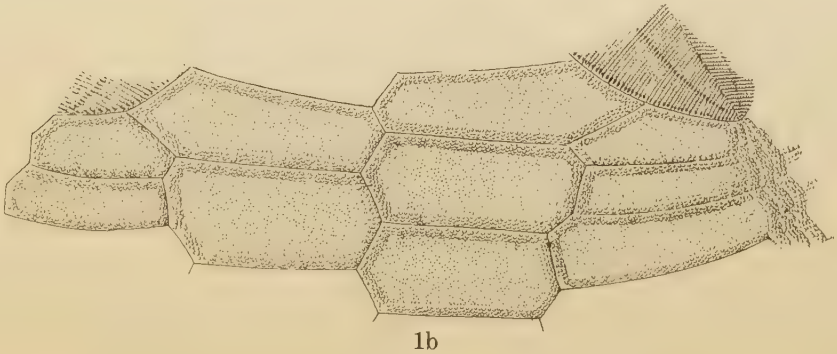
SCUTELLA NORRISI Pack (p. 186).

Univ. California, type.

FIGURE 9. Lower surface of the test.



1a



1b

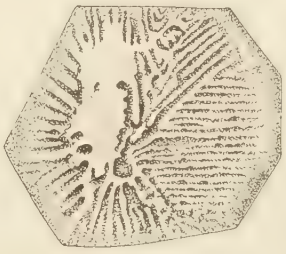
MIOCENE ECHINOIDEA.

PLATE LXXXVI.

SCUTELLA ABERTI Conrad (p. 187).

Maryland Geol. Survey.

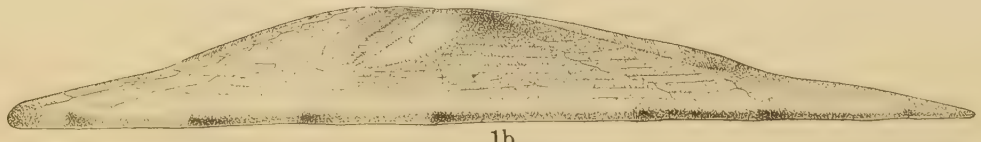
FIGURE 1a. Upper surface of the test.
1b. Enlarged plate of the same species.



1c

1d

1a



1b

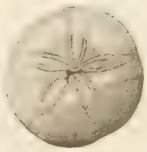
MIOCENE ECHINOIDEA.

PLATE LXXXVII.

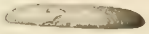
SCUTELLA ABERTI Conrad (p. 187).

Maryland Geol. Survey.

FIGURE 1a. Lower surface of the test.
1b. Lateral surface of the test.
1c. Interambulacral plate.
1d. Another view of same.



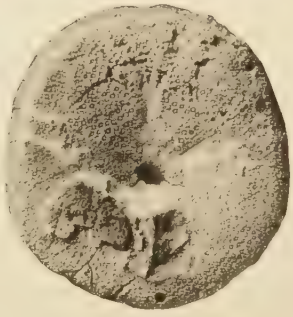
1a



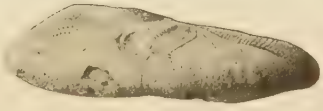
1b

2

3a

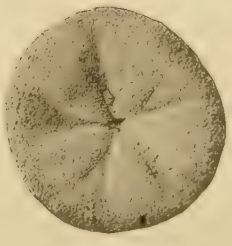


3b



3c

4a



4b

4c

4d

MIOCENE ECHINOIDEA.

PLATE LXXXVIII.

SCUTELLA GABBI (Rémond) Merriam (p. 189).

Univ. California 19425.

FIGURE 1a. Upper surface of the test.
1b. Lateral surface of the test.

DENDRASTER PERRINI (Weaver) (p. 190).

U. S. Nat. Mus. 165560, specimen A.

FIGURE 2. Upper surface of the test.

DENDRASTER PERRINI (Weaver) (p. 190).

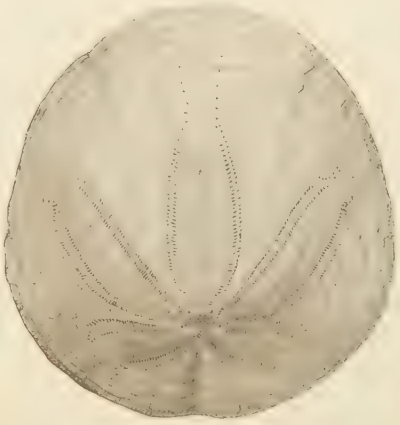
U. S. Nat. Mus. 165560, specimen B.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.

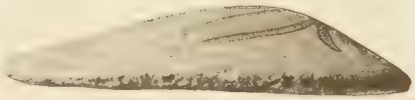
DENDRASTER ARNOLDI Twitchell, n. sp. (p. 192).

U. S. Nat. Mus. 165707, type.

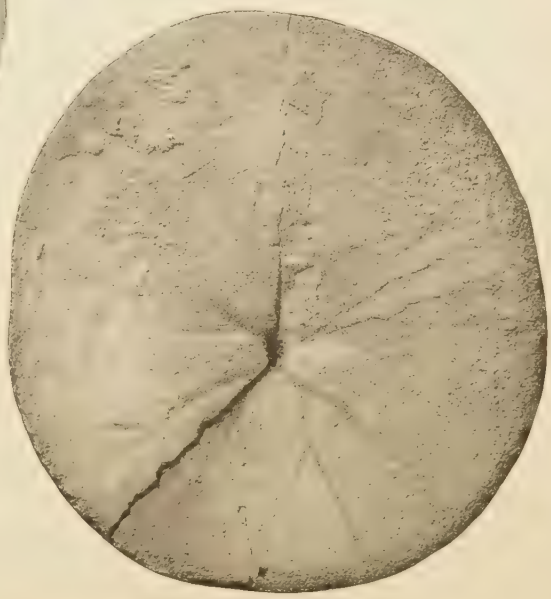
FIGURE 4a. Upper surface of the test.
4b. Lower surface of the test.
4c. Lateral surface of the test.
4d. Posterior surface of the test.



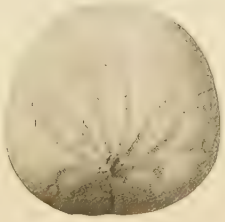
1a



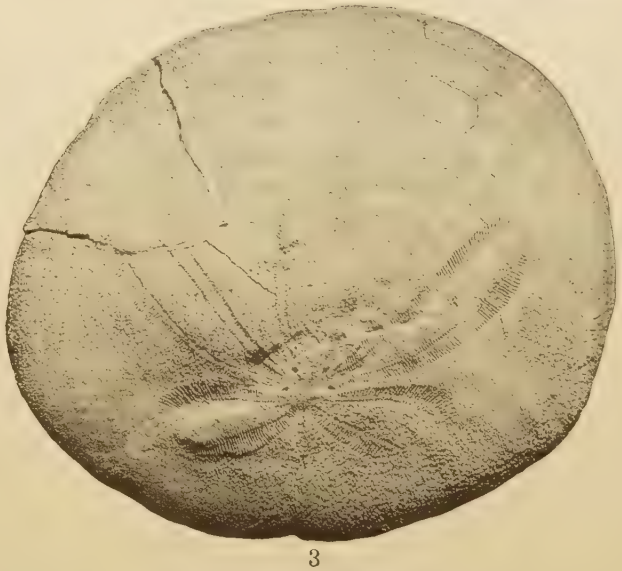
1b



2



4



3

MIOCENE ECHINOIDEA.

PLATE LXXXIX.

DENDRASTER GIBBSII (Rémond) (p. 193).

U. S. Nat. Mus. 165547, specimen A.

FIGURE 1a. Upper surface of the test.
1b. Lateral surface of the test.

DENDRASTER GIBBSII (Rémond) (p. 193).

U. S. Nat. Mus. 165611, specimen B.

FIGURE 2. Lower surface of the test.

DENDRASTER GIBBSII (Rémond) (p. 193).

U. S. Nat. Mus. 165611, specimen C.

FIGURE 3. Upper surface of the test.

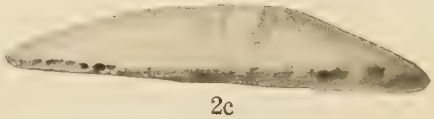
DENDRASTER GIBBSII (Rémond) (p. 193).

U. S. Nat. Mus. 165704, specimen D.

FIGURE 4. Upper surface of the test.

2a

1



2c

2b

MIOCENE ECHINOIDEA.

PLATE XC.

DENDRASTER OREGONENSIS (Clark) (p. 195).

U. S. Nat. Mus. 153975.

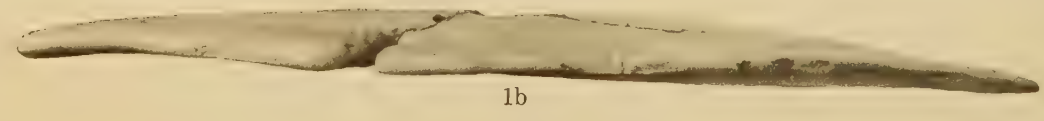
FIGURE 1. Upper surface of the test.

DENDRASTER COALINGAENSIS Twitchell, n. sp. (p. 196).

U. S Nat. Mus. 165537, type.

FIGURE 2a Upper surface of the test.
2b. Lower surface of the test, × 2.
2c. Lateral surface of the test, × 2.

1a



1b

PLATE XCI.

MELLITA CAROLINIANA Ravenel (p. 204).

Acad. Nat. Sci. Philadelphia 1083.

FIGURE 1a. Upper surface of the test.
1b. Lateral surface of the test.

320

1a

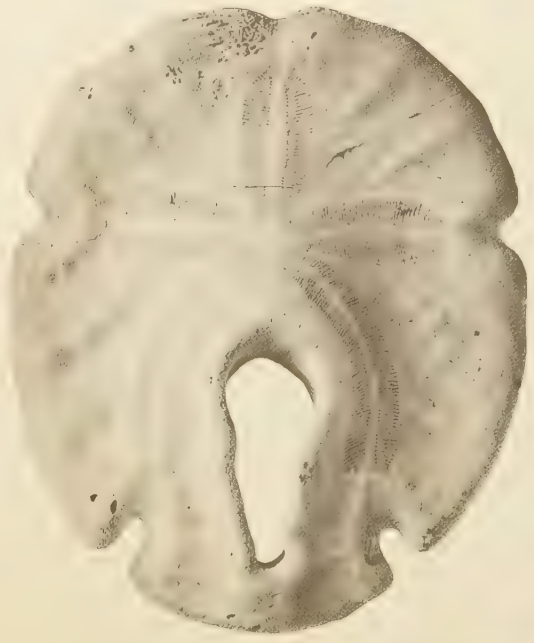
1b

PLATE XCII.

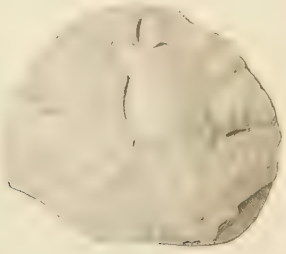
MELLITA CAROLINIANA Ravenel (p. 204).

Acad. Nat. Sci. Philadelphia 1083.

FIGURE 1a. Lower surface of the test.
1b. Posterior surface of the test.

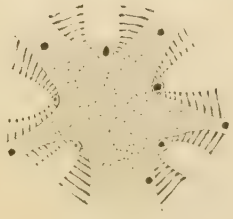


2a

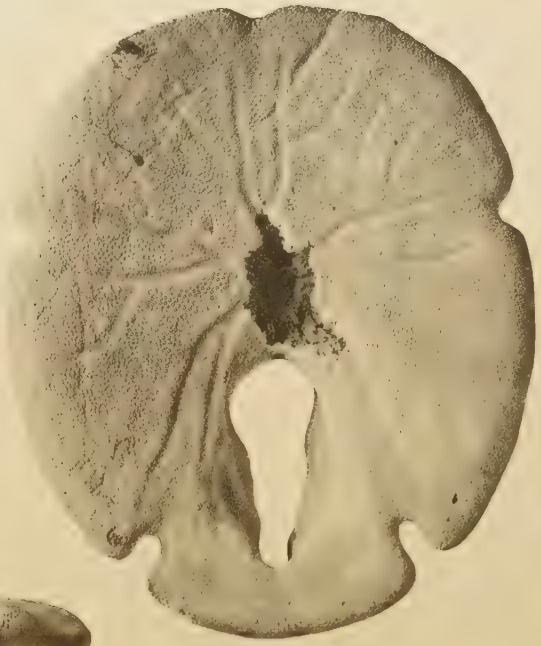


1

2c



2e



2b

2d

MIOCENE ECHINOIDEA.

PLATE XCIII.

SCUTASTER ANDERSONI Pack (p. 206).

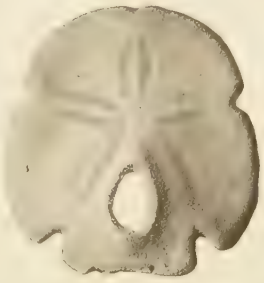
Univ. California, type.

FIGURE 1. Upper surface of the test.

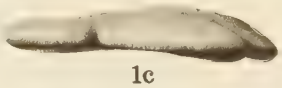
ENCOPE MACROPHORA Ravenel (p. 206).

Acad. Nat. Sci. Philadelphia 1086, specimen A.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.
2d. Posterior surface of the test.
2e. Apical system, × 3½.



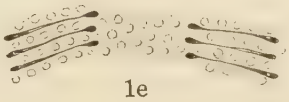
1a



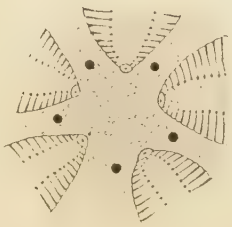
1c

1d

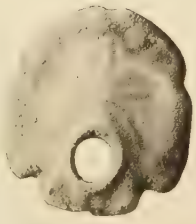
1b



1e



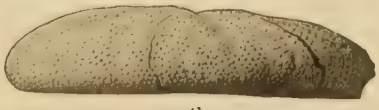
1f



2

3

4a



4b

MIOCENE ECHINOIDEA.

PLATE XCIV.

ENCOPE MACROPHORA Ravenel (p. 206).

U. S. Nat. Mus. 164658, specimen B.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.
1e. Part of one ambulacrum, × 8.
1f. Apical system, × 5.

ENCOPE MACROPHORA Ravenel (p. 206).

U. S. Nat. Mus. 9970, specimen C.

FIGURE 2. Upper surface of the test.

ASTRODAPSIS ANTISELLI Conrad (p. 198).

U. S. Nat. Mus. 165466, specimen A.

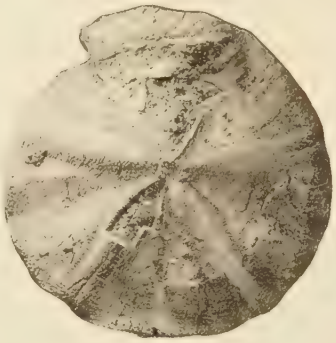
FIGURE 3. Upper surface of the test.

ASTRODAPSIS ANTISELLI Conrad (p. 198).

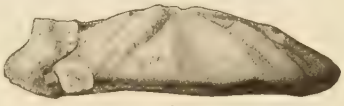
U. S. Nat. Mus. 165466a, specimen B.

FIGURE 4a. Lower surface of the test.
4b. Lateral surface of the test.

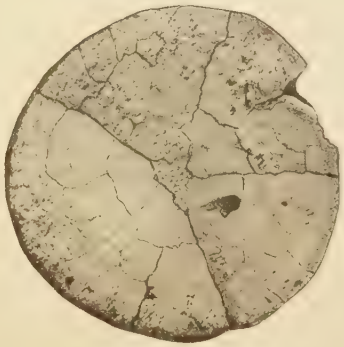
1



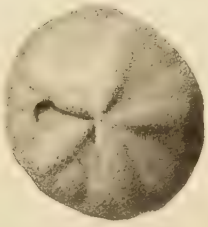
2a



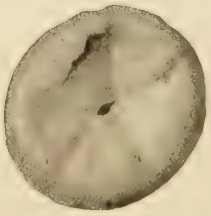
2c



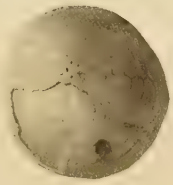
2b



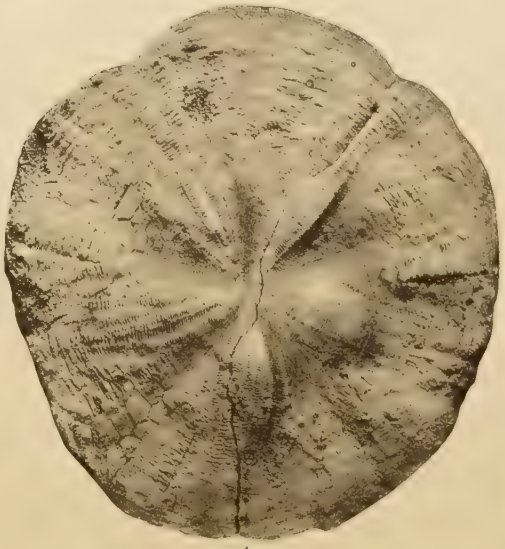
3a



3b

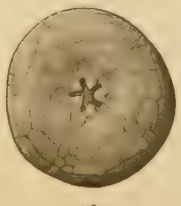


5a

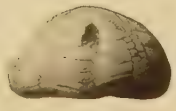


4

5c



5b



5d

MIOCENE ECHINOIDEA.

PLATE XCV.

ASTRODAPSIS ARNOLDI Twitchell, n. sp. (p. 199).

U. S. Nat. Mus. 165594, type.

FIGURE 1. Upper surface of the test.

ASTRODAPSIS WHITNEYI Rémond (p. 201).

Univ. California 19426.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.

ASTRODAPSIS TUMIDUS Rémond (p. 202).

Univ. California 19424.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.

ASTRODAPSIS JACALITOSENSIS Arnold (p. 203).

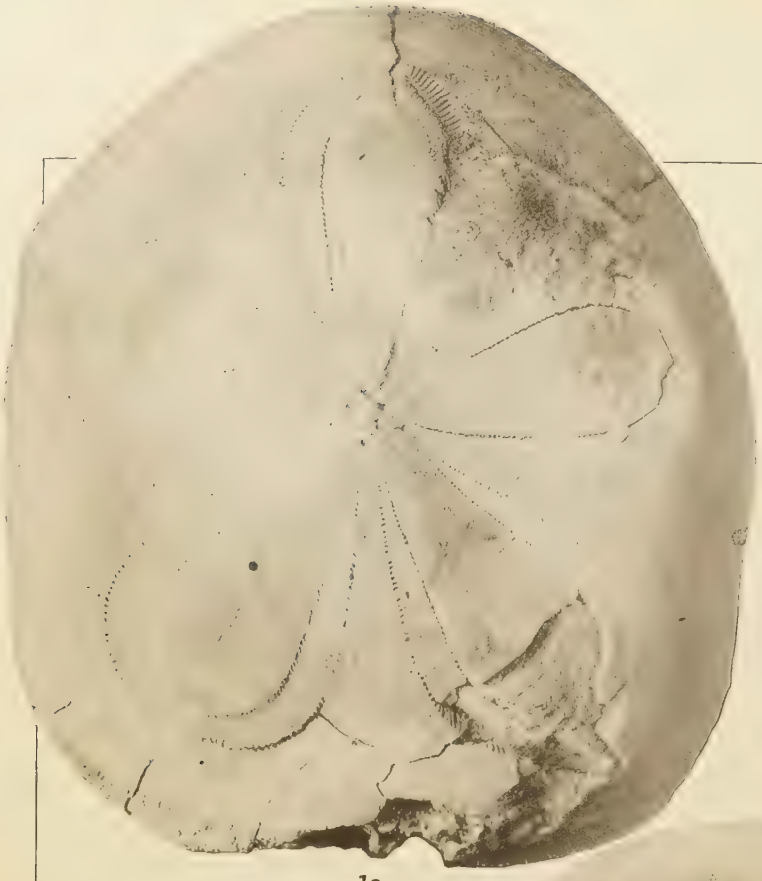
U. S. Nat. Mus. 165610, type.

FIGURE 4. Upper surface of the test.

CASSIDULUS BASSLERI Twitchell, n. sp. (211).

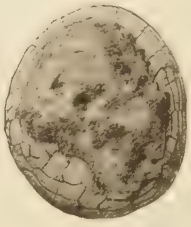
U. S. Nat. Mus. 9476, type.

FIGURE 5a. Upper surface of the test.
5b. Lower surface of the test.
5c. Lateral surface of the test.
5d. Posterior surface of the test.

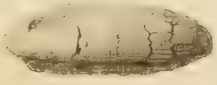


1a

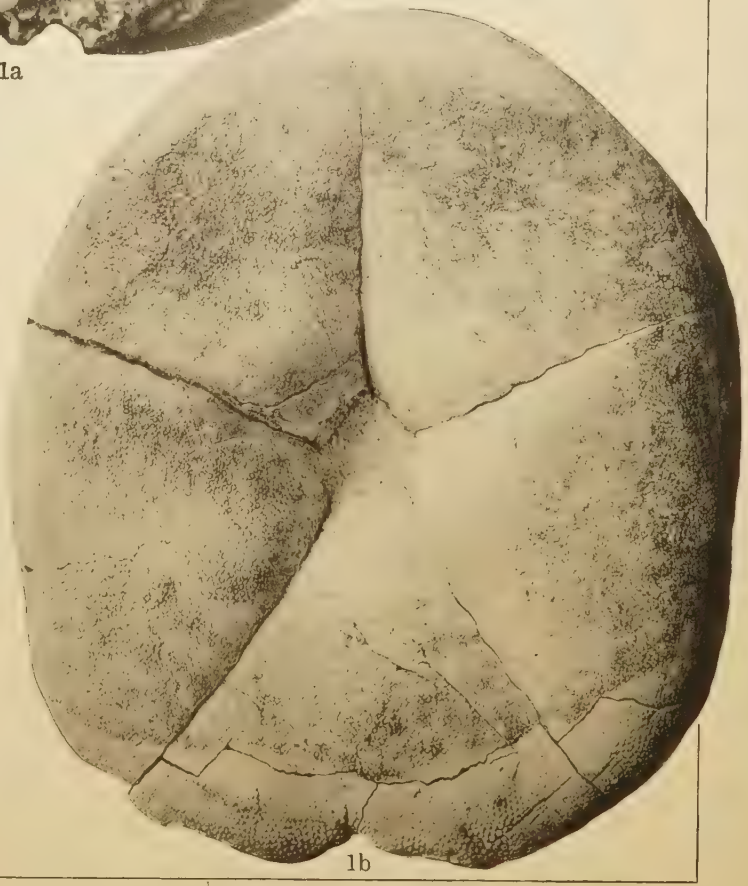
2a



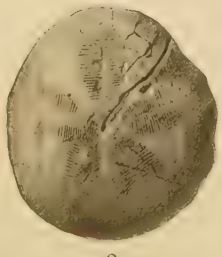
2b



2c



1b



3

MIOCENE ECHINOIDEA.

PLATE XCVI.

CLYPEASTER BOWERSI Weaver (p. 209).

Univ. California, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.

CLYPEASTER (?) BREWERIANUS (Rémond) (p. 210).

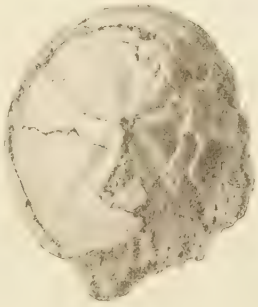
Acad. Nat. Sci. Philadelphia 1088, specimen A.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.

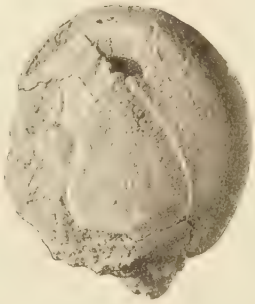
CLYPEASTER (?) BREWERIANUS (Rémond) (p. 210).

Univ. California 19423, specimen B.

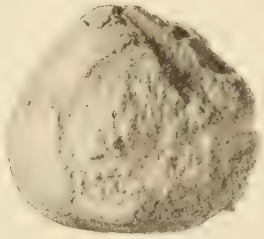
FIGURE 3. Upper surface of the test.



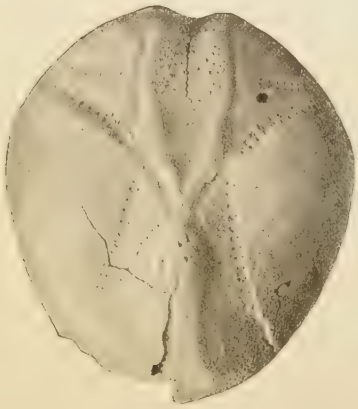
1a



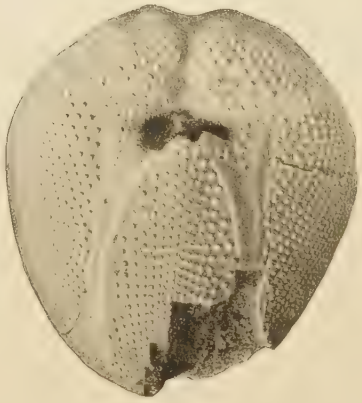
1b



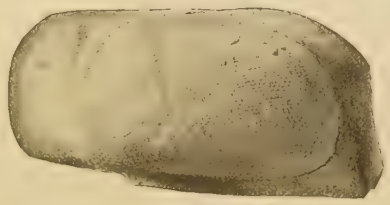
1c



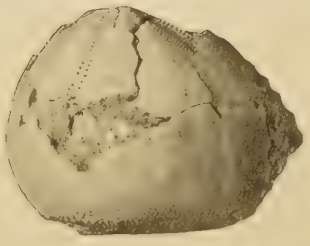
2a



2b



2c



1d

MIOCENE ECHINOIDEA.

PLATE XCVII.

AGASSIZIA PORIFERA (Ravenel) (p. 212).

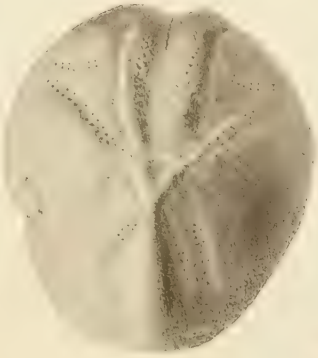
Am. Mus. Nat. Hist.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Posterior surface of the test.
1d. Lateral surface of the test.

ECHINOCARDIUM ORTHONOTUM Conrad (p. 213).

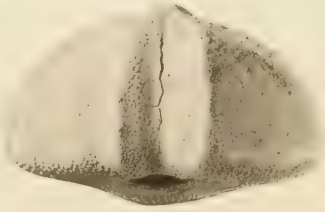
Acad. Nat. Sci. Philadelphia 1079.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.

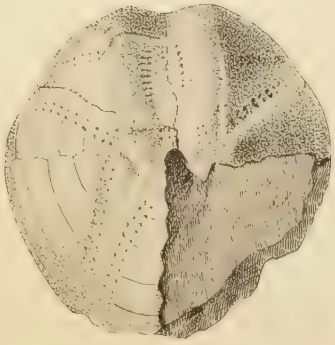


1a

1b



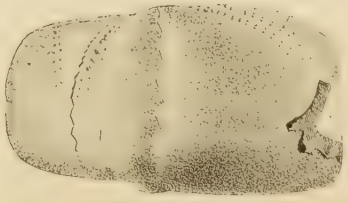
1c



2a

4

2b



2c

3a

3c

3b

MIOCENE ECHINOIDEA.

PLATE XCVIII.

ECHINOCARDIUM ORTHONOTUM Conrad (p. 214).

Am. Mus. Nat. Hist.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Anterior surface of the test.

ECHINOCARDIUM ORTHONOTUM Conrad (p. 214).

Johns Hopkins Univ. T 1002.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.
2c. Lateral surface of the test.

ECHINOCARDIUM DEPRESSUM Clark, n. sp. (p. 214).

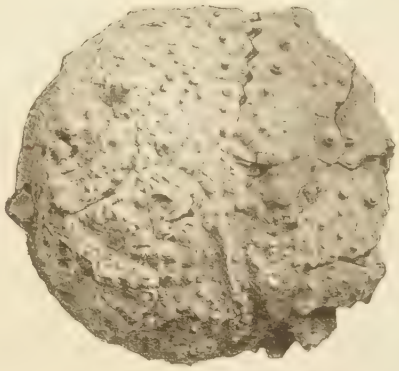
U. S. Nat. Mus. 164454, type.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.

LINTHIA (?) CALIFORNICA Weaver (p. 214).

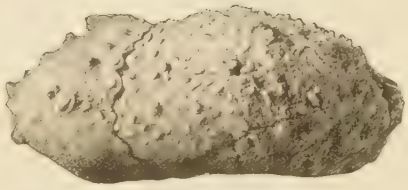
Univ. California, type.

FIGURE 4. Upper surface of the test.



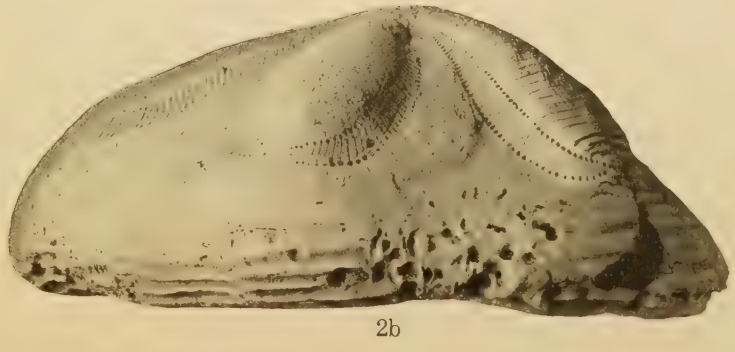
1a

1b



1c

2a



2b

PLIOCENE ECHINOIDEA.

PLATE XCIX.

STRONGYLOCENTROTUS DRÖBACHIENSIS (Müller) (p. 216).

Wagner Free Inst. Sci. 4350.

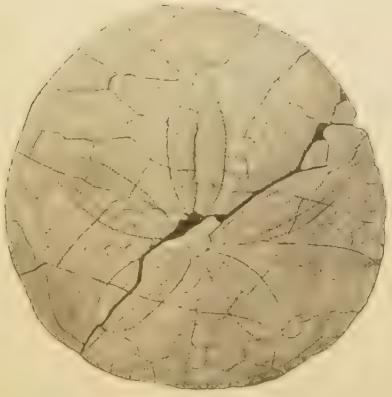
FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.

DIPLOTHECANTHUS DALLI Twitchell, n. sp. (p. 218).

U. S. Nat. Mus. 164670.

FIGURE 2a. Posterior surface of the test.
2b. Lateral surface of the test.

1a



2a

2b

1b

PLIOCENE ECHINOIDEA.

PLATE C.

DIPLOTHECANTHUS DALLI Twitchell, n. sp. (p. 218).

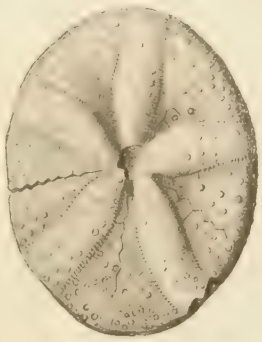
U. S. Nat. Mus. 164670, type.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.

DENDRASTER INTERLINEATUS (Stimpson) (p. 216).

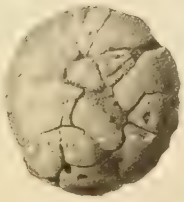
Univ. California 19427.

FIGURE 2a. Upper surface of the test.
2b. Lower surface of the test.

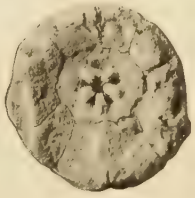


1

2



3a



3b

3c

3d

PLIOCENE ECHINOIDEA.

PLATE CI.

ASTRODAPSIS FERNANDOENSIS Pack (p. 217).

Univ. California, specimen A.

FIGURE 1. Upper surface of the test.

ASTRODAPSIS FERNANDOENSIS Pack (p. 217).

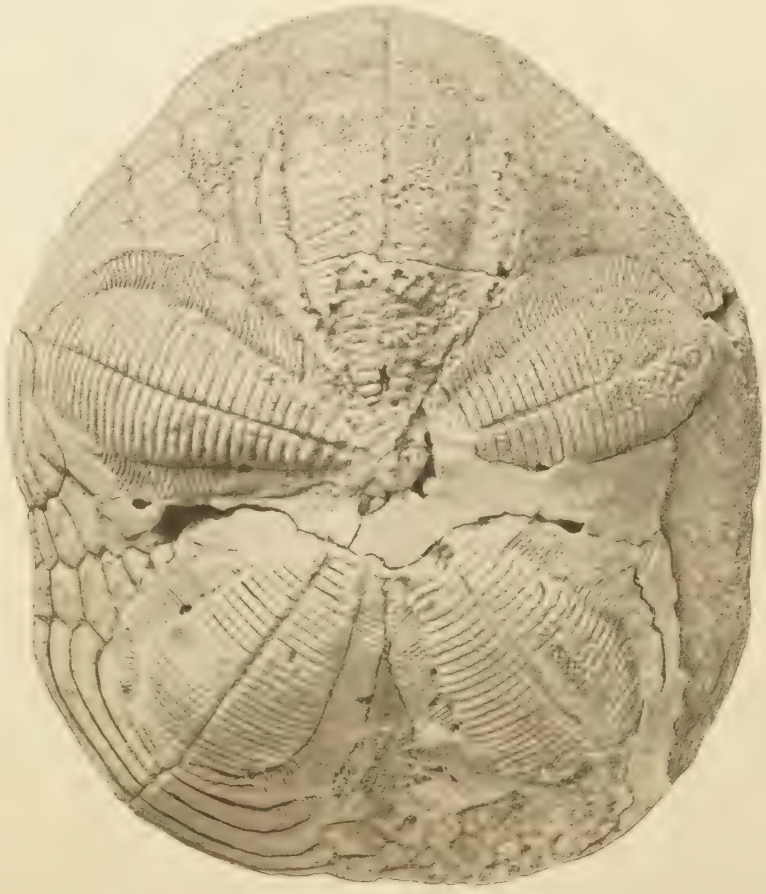
Univ. California, specimen B.

FIGURE 2. Lower surface of the test.

CASSIDULUS BERRYI Twitchell, n. sp. (p. 220).

Johns Hopkins Univ. T 1, type.

FIGURE 3a. Upper surface of the test.
3b. Lower surface of the test.
3c. Lateral surface of the test.
3d. Posterior surface of the test.



1a

1b

PLATE CII.

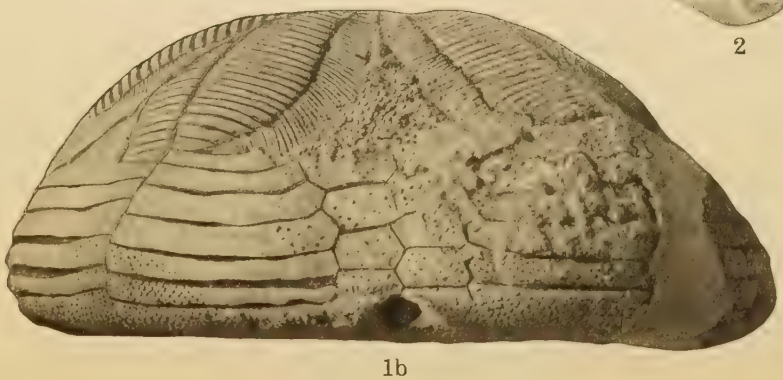
DIPLOTHECANTHUS ROSACEUS (Lamarck) (p. 219).

U. S. Nat. Mus. 165693.

FIGURE 1a. Upper surface of the test.
1b. Lateral surface of the test.

1a

2



1b

PLATE CIII.

DIPLOTHECANTHUS ROSACEUS (Lamarck) (p. 219).

U. S. Nat. Mus. 165693.

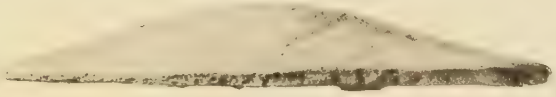
FIGURE 1a. Lower surface of the test.
1b. Posterior surface of the test.

SCHIZASTER (?) STALDERI Weaver (p. 221).

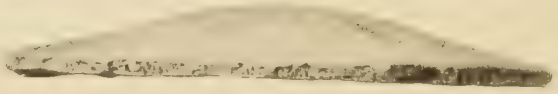
Univ. California, type.

FIGURE 2. Upper surface of the test.

1a



1c



1d

1b

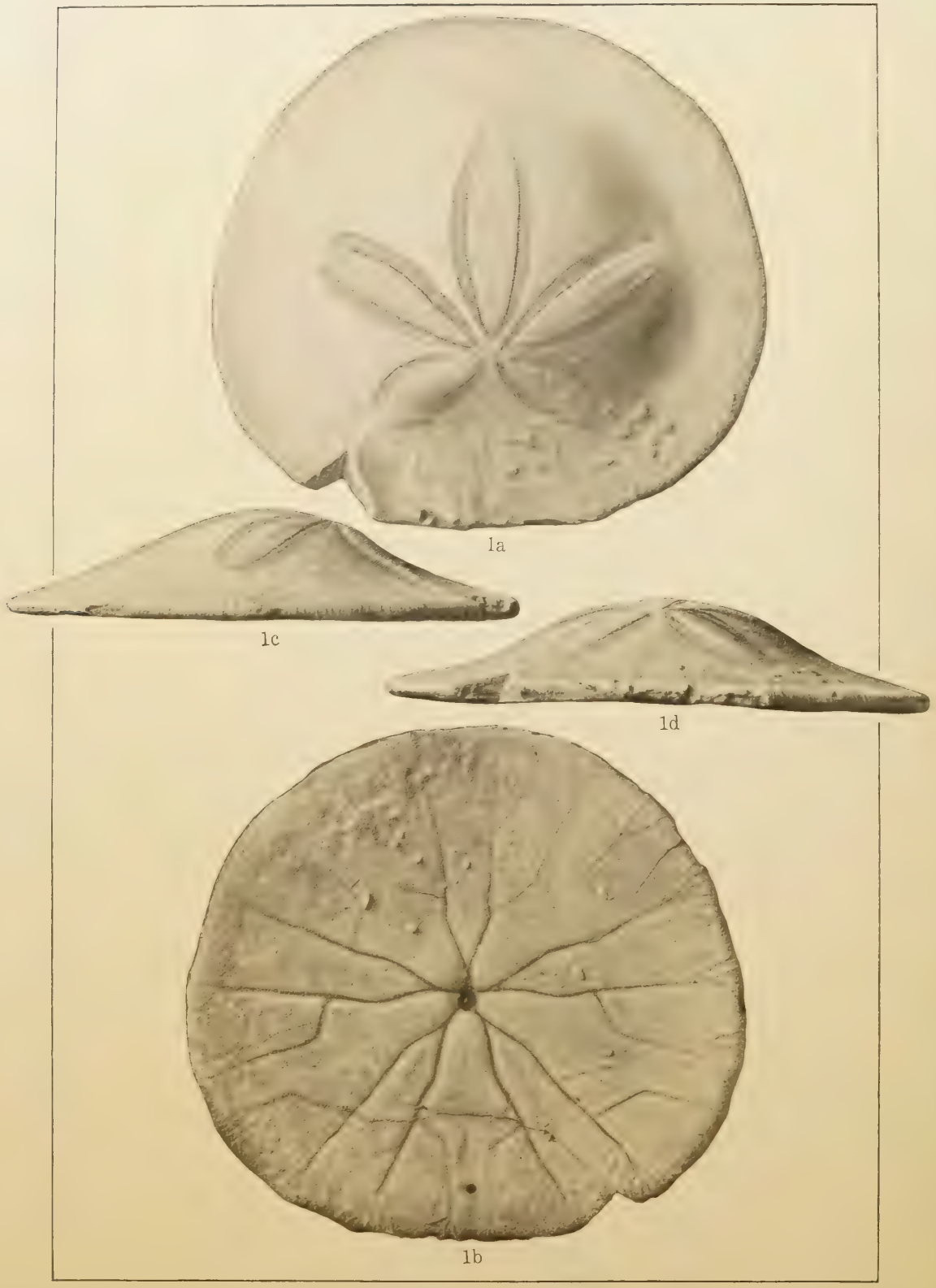
PLEISTOCENE ECHINOIDEA.

PLATE CIV.

DENDRASTER EXCENTRICUS (Eschscholtz) (p. 223).

Wagner Free Inst. Sci. 2473, specimen A.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.



1a

1c

1d

1b

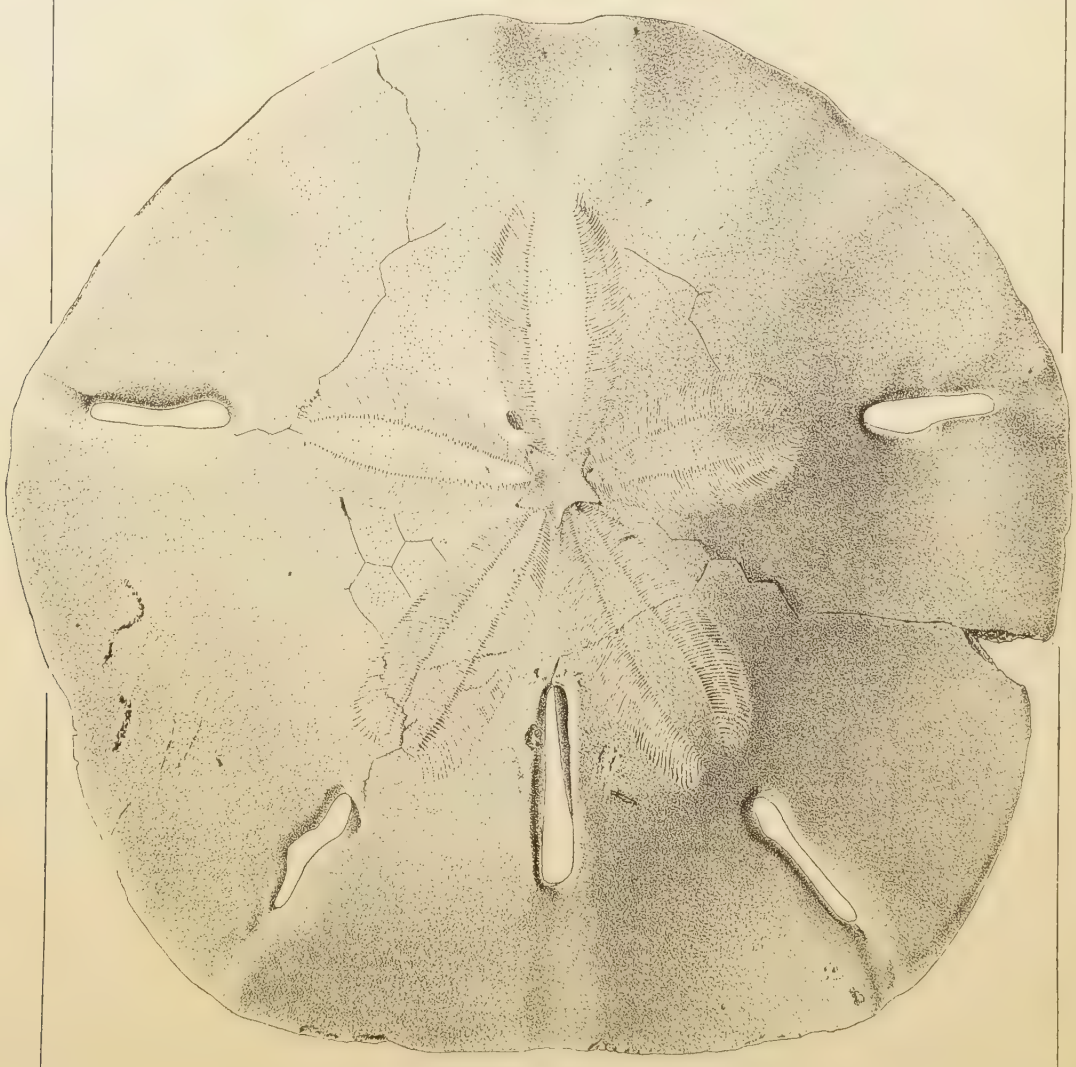
PLEISTOCENE ECHINOIDEA.

PLATE CV.

DENDRASTER EXCENTRICUS (Eschscholtz) (p. 223).

Johns Hopkins Univ. T 2, specimen B.

FIGURE 1a. Upper surface of the test.
1b. Lower surface of the test.
1c. Lateral surface of the test.
1d. Posterior surface of the test.



1

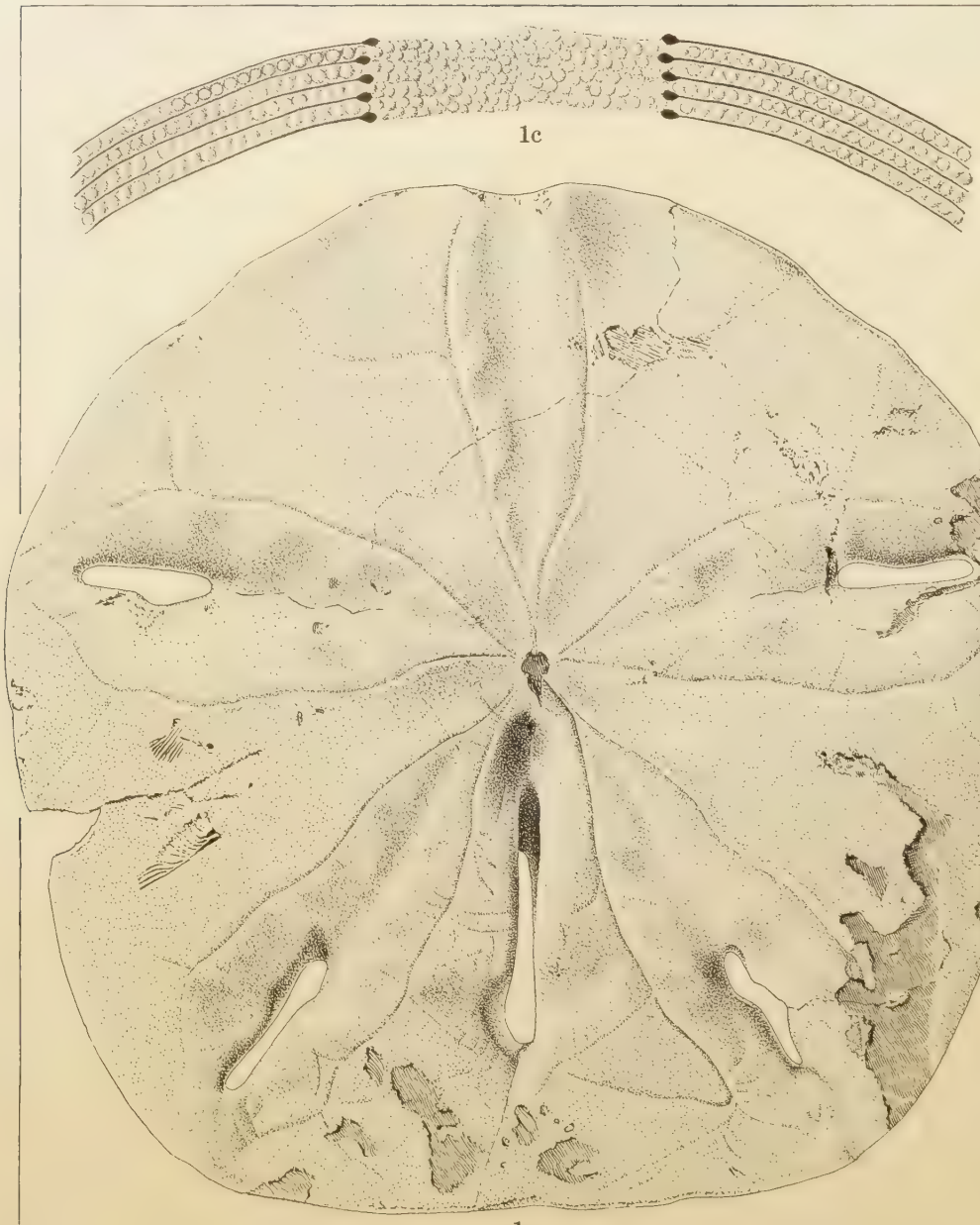
PLEISTOCENE ECHINOIDEA.

PLATE CVI.

MELLITA PENTAPORA (Gmelin) (p. 225).

Johns Hopkins Univ. T 3.

Upper surface of the test.



1c

1a

1b

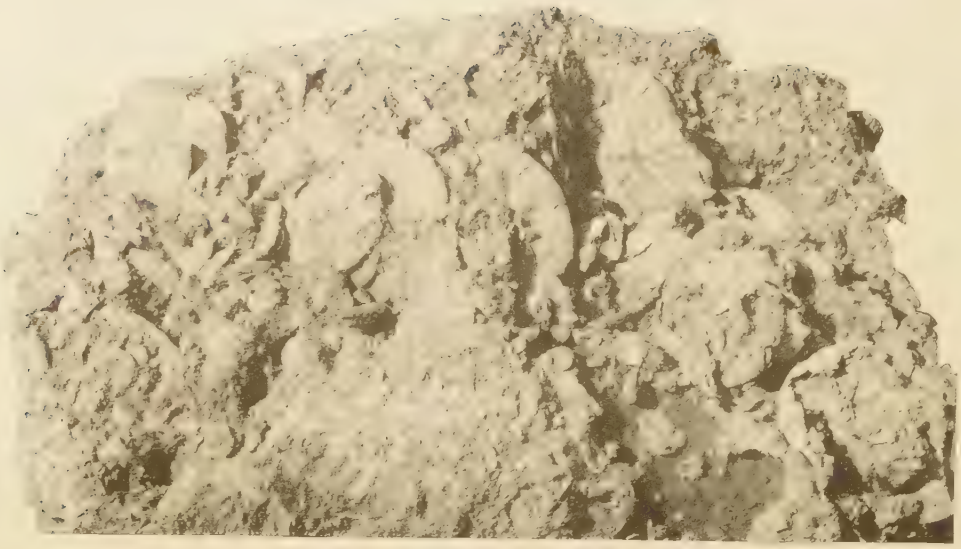
PLEISTOCENE ECHINOIDEA.

PLATE CVII.

MELLITA PENTAPORA (Gmelin) (p. 225).

Johns Hopkins Univ. T 4, type.

FIGURE 1a. Lower surface of the test.
1b. Posterior surface of the test.
1c. Part of an ambulacrum, × 6.



A. ASTRODAPSIS TUMIDUS REMOND IN MATRIX, SANTA MARGARITA FORMATION (UPPER MIOCENE), NACIMIENTO RIVER, SAN LUIS OBISPO COUNTY, CAL.

B. DENDRASTER GIBBSII (REMOND) IN UPPER MIOCENE (?) BEDS, K. W. JONES RANCH, KINGS COUNTY, 20 MILES SOUTHEAST OF COALINGA, FRESNO COUNTY, CAL.

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Names in *italic* are synonyms; figures in *italic* refer to illustrations; figures in **black face** refer to descriptions.

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BIOGRAPHY

Mayville William Twitchell was born in Washington, D. C., October 14, 1868. His early education was obtained in the public schools of Washington and at Cooper Institute, New York, and Pratt Institute, Brooklyn. He was a draftsman and assistant mineralogist with Munn & Company, publishers of the *Scientific American*, New York, from 1888 to September 1893 when he resigned to enter the Columbian University (now George Washington University) at Washington, D. C. In 1899 he received from Columbian University the degree of "Bachelor of Science in Geology and Mineralogy" and in 1900, after a year's advanced study in Mineralogy and the presentation of a thesis on "Goniometry," was granted the degree of "Master of Science." From December 1899 to January 1901 he was assistant in Geology; from January 1901 to October 1904, Instructor in Geology, and from October 1904 to January 1905, Instructor in Mineralogy at Columbian University. He entered Johns Hopkins University in October 1901 where he pursued studies in Geology under Professor Clark, Professor Reid, Professor Mathews, Doctor Shattuck, Doctor Fassig, and a number of special lecturers; and studies in general Biology under Doctor Andrews. During the years 1901-02 and 1902-03 he was a Student Assistant and in 1903-04 held the University Scholarship in Geology. During the summers of 1902, 1903, and a part of 1904 he was engaged in field work for the Maryland Geological Survey in the Coastal Plain Region of Maryland. Since July 1904 he has been regularly employed for a part of the time in editorial and miscellaneous office work for the Maryland Geological Survey.

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